Integrating Occupational Characteristics into Human Performance Models: IPME versus ISMAT Approach

Prepared By:
Christy Lorenzen
Alion Science & Technology
MA&D Operation
4949 Pearl East Circle, Suite 200
Boulder, CO 80301

Contract Scientific Authority:
CSA: Dr. Wenbi Wang, Research Engineer – HSI Section, 416-635-2000 ext 3063

The scientific or technical validity of this Contract Report is entirely the responsibility of the Contractor and the contents do not necessarily have the approval or endorsement of Defence R&D Canada.

Defence R&D Canada – Toronto

Contract Report

DRDC CR 2009-059

August 2009

Principal Author

Original signed by Christy M. Lorenzen

Christy M. Lorenzen

Senior Systems Analyst

Approved by

Original signed by Dr. Wenbi Wang

Dr. Wenbi Wang
Research Engineer - HSI Section

Approved for release by

Original signed by K. C. Wulterkens

K. C. Wulterkens

for Chair, Document Review and Library Committee

Prepared for Contract W7711-057948.

Abstract

This project studied the incorporation of military occupational data into generic human performance modeling software, the Integrated Performance Modelling Environment (IPME). It has explored the use of modeling and simulation (M&S) for addressing the Canadian Forces (CF) personnel and manpower issues. A set of Canadian Air Force occupational specification data were integrated into IPME. This report documents an effort to validate this new modeling capability. An IPME model of an Unmanned Aerial Vehicle (UAV) mission was created. The modeled crew consisted of operators defined by job-related task, skill and knowledge statements obtained from the occupational data. For this IPME model, we used a job similarity index to predict operator performance. To confirm the validity of this approach, we planned to replicate the same UAV model in the US Army's IMPRINT and compare the performance predictions made by the two modeling toolkits. However, due to the lack of access to IMPRINT, the Integrated Simulation Manpower Analysis Tool (ISMAT) was used instead. As a personnel modeling tool, ISMAT was developed primarily for targeting naval applications. This limited our ability to validate the IPME UAV model which used Air Force occupational data. As a result, the current study focused on comparing the personnel modeling approaches adopted by IPME and ISMAT. The differences are documented, and they provide insight into future IPME research and development.

Résumé

L’objet du projet était d’étudier l’intégration de données sur les groupes professionnels militaires dans un logiciel de modélisation générique de la performance humaine appelé Integrated Performance Modelling Environment (IPME). Ce projet a permis d’explorer l’utilisation de la modélisation et de la simulation (M&S) pour tenter de résoudre les problèmes de personnel et de main-d’œuvre au sein des FC. Plus particulièrement, un ensemble de données sur la structure des groupes professionnels militaires de l’Aviation canadienne a été intégré dans IPME. L’étude menée documente les efforts déployés pour valider ce nouveau logiciel de modélisation. La mission des engins télépilotés (UAV) modélisée dans IPME reposait sur les travaux de Kobierski (2004). L’équipage du modèle consiste en opérateurs définis par les énoncés de tâches, d’habiletés et de connaissances reliées au travail, établis à partir des données sur les groupes professionnels. Nous avons utilisé un index de similitude des emplois (Farrell et al., 2006), basé sur les données sur les tâches intégrées dans le modèle, comme indicateur pour prédire la performance des opérateurs. Pour confirmer la validité de cette approche, nous avions initialement prévu de reproduire le même modèle d’engin piloté (UAV) dans l’outil IMPRINT (Improved Performance Research Integration Tool) de l’Armée américaine et de comparer ensuite les prévisions en matière de performance produites par ces deux boîtes à outils de modélisation. Cependant, comme IMPRINT n’était pas accessible, c’est l’outil ISMAT (Integrated Simulation Manpower Analysis Tool) qui a été utilisé à la place. En tant qu’outil de modélisation du personnel, ISMAT a été développé essentiellement pour cibler les applications navales. Par conséquent, cette étude a surtout consisté à comparer les approches de modélisation du personnel différentes que sont IPME et ISMAT. Les différences entre les deux sont documentées dans ce rapport, l’accent étant mis sur les orientations futures de la recherche et du développement portant sur IPME.

Executive summary

Integrating Occupational Characteristics into Human Performance Models: IPME versus ISMAT Approach

Christy Lorenzen, Alion Science & Technology; DRDC CR 2009-059; Defence R&D Canada – Toronto; August 2009.

Introduction or background: The Integrated Performance Modelling Environment (IPME) is a discrete-event simulation software for developing computational human performance models. Prior to this project, IPME lacked data for precisely representing military personnel, particularly the knowledge and skills that military operators obtained through their professional training. A need was identified to incorporate military occupational data into IPME so that models could be more easily constructed to address issues in the personnel and manpower domains. An applied research project entitled *The Addition of the Canadian Air Force Military Occupational Structure Identification Code (MOSID) into IPME* was initiated. Its primary objective was to expand IPME's modeling capability and address a wider range of Human Systems Integration (HSI) issues. Specifically, this project focused on the integration of the Canadian Air Force occupational data into IPME.

There were four main tasks in this project: (1) identify elements from the available occupational data that are relevant to computational human performance models; (2) link a military occupational database to IPME; (3) apply occupational data in human performance models; and (4) verify and validate this new modeling capability by comparing it with other modeling toolkits.

With this project effort, analysts can now represent operators' MOS-related professional knowledge and skills in IPME models. Thus, it is possible to evaluate whether, for example, operators are qualified to perform an assigned task. In this project, we explored the use of a Job Similarity Index (JSI) for quantitatively measuring operator competency for designated tasks. This report documents a validation study that compared two different methods for applying occupational data in human performance models.

This study focused on a contrived Uninhabited Aerial Vehicle (UAV) operator selection task. The newly acquired occupational (e.g., knowledge and skills) data were used both in the IPME crew model as operators' traits, and in the IPME task network model for specifying task requirements. It allowed analysts to conduct a gap analysis and assess which operators were better qualified to perform the assigned tasks. To examine the validity of the IPME modeling process, the UAV model was later recreated in a modeling software application called Integrated Simulation Manpower Analysis Tool (ISMAT).

Results: The study compared two ways to represent operator knowledge and skill traits in a simulation model and demonstrated how such traits were applied in operator qualification predictions. Although both represented acceptable approaches for personnel modeling, it revealed that an integration of certain ISMAT features (e.g., the use of a generic human skill taxonomy) into IPME would further enhance IPME's capabilities.

Significance: With the addition of the Canadian Air Force occupational attributes to IPME, analysts should be able to represent an operator's professional knowledge and skills in a model and simulate Air

Force personnel more precisely. Such capability paves the way for the use of modeling and simulation to address future personnel and staffing issues.

Future plans: The contrast between IPME and ISMAT revealed a significant gap between the two modeling platforms. The study identified future development needs for IPME: specifically, the introduction of generic human skill taxonomy for linking operator tasks to occupational knowledge and skills. Such development will reduce analysts' effort in applying occupational attributes during model construction and further improve the representation of operator characteristics in human performance models.

Sommaire

Intégration des caractéristiques des groupes professionnels dans des modèles de performance humaine : l'approche IPME et l'approche ISMAT

Par Christy Lorenzen; RDDC RC 2009-059; R & D pour la défense Canada – Toronto; avril 2009.

Introduction ou contexte : L'outil IPME **(**Integrated Performance Modelling Environment) est une application de simulation d'événements discrets disponible sur le marché et servant à développer des modèles qui simulent la performance humaine et de systèmes. On s'est rendu compte qu'il était nécessaire d'ajouter au logiciel IPME des données provenant de deux domaines MANPRINT de l'Armée américaine (MANpower et PeRsonnel INTegration) **-** personnel et main-d'oeuvre – étant donné que la sensibilité de IPME à l'égard de ce type de données a été jusqu'ici minime. À cette fin, on a donc entrepris le projet triennal, *L'Ajout du code d'Identification de la structure des groupes professionnels militaire (IDSGPM) dans IPME,* et amélioré cet outil en y ajoutant des modèles provenant de ces domaines MANPRINT dans le but de procurer une fonction d'intégration de systèmes humains à la Force aérienne des FC.

Comme il n'y avait pas de données sur le personnel dans les outils de modélisation, on a ajouté à IDME un lien vers les données sur la structure des groupes professionnels militaires. Le lien a permis aux modélisateurs d'ajouter, aux modèles d'équipage dans IPME, des niveaux de compétence pour les énoncés de tâches, d'habiletés et de connaissances reliées au travail. Il a ainsi été possible d'évaluer si un opérateur était capable d'accomplir la tâche qui lui est confiée en comparant le niveau de compétence établi pour cette tâche au niveau d'effort que cette dernière exigeait. Le résultat de cette évaluation (calcul) a été un index de similitude des emplois (ISE).

On a ensuite entrepris des travaux de validation pour vérifier les prédictions obtenues à l'aide du modèle IPME. Aux fins de cette expérimentation, on a créé un modèle d'engin téléguidé fondé sur une étude de modélisation d'engins téléguidés antérieure. On a fait appel au nouveau lien IPME-MOSID pour concevoir le modèle d'équipage et affecté les tâches d'un niveau minimum d'effort requis. Les résultats du modèle permettaient de prédire, d'après la valeur ISE d'un opérateur, que celui-ci accomplirait mieux la tâche que d'autres.

Initialement, on avait prévu de valider les résultats obtenus au moyen d'IPME en les comparant à ceux du même modèle construit dans IMPRINT. On en a toutefois été empêché en raison de restrictions à l'exportation imposées à IMPRINT. Pour cette raison, nous avons essayé de valider les résultats obtenus à l'aide d'IPME en les comparant à ceux du même modèle dans un autre outil de simulation appelé ISMAT (Integrated Simulation Manpower Analysis Tool). En raison de la différence intrinsèque qui existe entre les deux outils de modélisation, une comparaison directe des résultats du modèle était impossible, ce qui explique que l'étude a consisté essentiellement à mettre en opposition les approches de modélisation du personnel différentes d'IPME et d'ISMAT.

Résultats : L'étude a montré qu'il y avait deux façons différentes de représenter les connaissances, les habiletés et les caractéristiques des opérateurs dans un modèle de simulation et de quelle manière ces caractéristiques étaient appliquées aux prédictions de la performance des systèmes. Malgré le fait que les approches de modélisation du personnel étaient toutes deux des approches acceptables, cette étude a

révélé que l’intégration de certaines caractéristiques d’ISMAT, p. ex., l’utilisation d’une classification taxinomique générique des qualités humaines, bonifierait davantage les fonctionnalités d’IPME.

Signification : L’ajout à IPME des attributs des groupes professionnels militaires permettra aux analystes de représenter les connaissances et les habiletés que les opérateurs acquièrent dans le cadre de leur instruction professionnelle. Le fait de pouvoir rendre compte de ces éléments caractéristiques des opérateurs permettra aux analystes d’explorer la possibilité d’utiliser la M&S pour les activités reliées au personnel et à la dotation.

Plans futurs : En permettant de comparer IPME à ISMAT, cette étude a mis au jour l’écart qui existe actuellement entre ces deux jeux d’outils de modélisation et a servi à déterminer les besoins en matière de développement futur d’IPME, en particulier l’ajout d’une classification taxinomique générique des qualités humaines, p. ex., l’ensemble de compétences Fleishmann. Il serait ainsi possible de définir les tâches exécutées par l’homme (comme dans un modèle de réseau de tâches IPME) du point de vue des connaissances, des compétences et des habiletés requises pour les accomplir. De tels progrès permettraient de faire avancer encore plus la représentation des caractéristiques humaines dans les modèles de performance.

Table of contents

List of figures

List of tables

Acknowledgements

First, thank you to Dr. Wenbi Wang for his direction, creativity, and sense of humour. Thank you to Dr. Phil Farrell for enlightening discussions and advice. Finally, thank you to Dr. Ming Hou and the CMC team whose efforts described in their final report were critical to the success of this project.

This page intentionally left blank.

1 Introduction

The Integrated Performance Modelling Environment (IPME) is a commercially-available discrete-event simulation application used for developing models that simulate human and system performance. The application contains algorithms for calculating operators' workload and predicting the effects of stressors on performance [1]. IPME has been a jointly developed by Defence Research and Development Canada – Toronto (DRDC Toronto), QinetiQ Centre for Human Sciences (CHS), and Alion Science and Technology-MA&D Operation. It is one of the tools used by the Canadian Air Force for capturing system (including human) requirements in human systems integration (HSI) studies.

A need was identified to add information to IPME from two United States (US) Army MANPRINT (MANpower and PeRsonnel INTegration) domains - personnel and manpower. Prior to this effort, the sensitivity of IPME to this type of information has been minimal. An applied research project entitled *The Addition of the Canadian Air Force Military Occupational Structure Identification Code (MOSID) for IPME* was initiated in 2005. Its purpose was to enhance IPME with models from those MANPRINT domains and to improve the HSI capability for the Canadian Air Force. Note that although the acronym MOSID generally refers to a 5-digit occupational code, for convenience in this report, we use the term to refer to occupational characteristics that are captured in occupational specifications unless otherwise specified. The goals of this project were three-fold:

1. To improve and increase the amount of *built-in data* for analysts to use in their IPME models;

2. To provide a simpler modeling method for examining issues in the manpower, personnel, and training domains; and

3. To allow analysts to use occupational specifications, training data and requirements in their models to examine *operator performance* and analyse *system staffing*.

The addition of the MOSID to IPME will enhance the capability to conduct human-system analyses that include occupational characteristics of personnel (i.e., the operators or users of the equipment). The intent is that the new capability resulting from this project can be used for investigating manning concepts for new systems, and for supporting future capability development and engineering process improvement.

The project consists of three phases.The first phase focused on database creation and generated two artifacts: a database that encapsulated occupational characteristics for a selected Canadian Air Force occupations and a Java database access application, CF Air Force MOSID Application (CAMA). While this project was conducted, a significant effort was made by the Canadian Forces to modernize the military occupational structure. This effort was spearheaded by the MOSART project (Military Occupational Structure Analysis, Redesign and Tailoring). Outputs from MOSART included the newly designed occupational specifications, which provided the foundation of occupational data that were later incorporated into IPME. Such Military Occupational Specification (MOS) data were stored in a relational database, independent of a

modeling platform (e.g., IPME). CAMA allows users to perform basic functions for managing the relational database, such as searching through the MOS database or making data edits.

The second phase produced a MOSID plug-in that was integrated into IPME and improved CAMA's search capability. The MOSID plug-in serves as a bridge between the MOS data and IPME, and allows an analyst to easily load task and knowledge statements from the MOS database into an IPME model. Such task and knowledge information can also be associated with model tasks through task expression logic. When an IPME model is executed, a Job Similarity Index (JSI), (as described in [2]), can be computed to estimate the level of match between operators with specific skill sets and their designated tasks.

The third phase of the project involved a study that contrasted two different modeling approaches for addressing manpower issues. An Uninhabited Air Vehicle (UAV) operator selection task was used as a test case. An IPME UAV model, created previously for a separate project [4], was used as a baseline and further modified by incorporating occupational data. This model was later translated into the Integrated Simulation Manpower Analysis Tool (ISMAT). The different methods used in IPME and ISMAT for processing occupational data were compared and reported in this document.

Table 1 provides a detailed chronological description of key project activites.

Table 1: The Addition of the CF AF MOSID into the IPME Project Tasks

Year 1	1. Communicate with Human Resources – Military (HR(mil)) and coordinate with the Military Occupational Structure Analysis, Redesign, and Tailoring (MOSART) project.
	2. Design and populate a database with MOS data. Document the database design.
	3. Design and create a user interface called the CF AF MOSID Application (CAMA) to view and edit the MOS database.
Year 2	1. Update CAMA with new data received from MOSART.
	2. Coordinate with the Canadian Forces Experimentation Centre (CFEC) on the Uninhabited Aerial Vehicle (UAV) crew selection study and prepare the scenario for the validation experiment.
	3. Under the guidance of the Scientific Authority (SA), create an experiment plan for validating IPME's newly added capability.

Year 3	1. Add the capability to IPME to access the MOSID database and incorporate the data in a model.
	2. Create a UAV model for a crew selection task using IPME.
	3. Validate IPME's new capability by contrasting the UAV model prediction to the results obtained in the CFEC study.
	4. Create the same UAV model in the Integrated Simulation Manpower Analysis Tool (ISMAT).
	5. Compare how IPME and ISMAT use personnel and manpower data in terms of the UAV models that were created. Compare results from these two models.

Work on this project began with Military Occupational Code (MOC) documents received from the Scientific Authority (SA). These documents allowed the design and population of a prototype database using Microsoft Access, which formed the basis of the initial version of CAMA. Table 2 shows the list of Air Force occupations included in this MOC database.

.

Table 2: Initial Set of Occupations Included in the Prototype Database

Occupation	MOC	MOSID
Aviation Systems Technician	514	00135
Air Navigator	031	00182
Aerospace Control	039	00184
Airfield Engineering	046	00189
Aerospace Control Operator	168	00337

These MOC documents contain occupational identifiers and descriptions of occupational classifications, working conditions, career development plans, and job performance requirements.

Such information is frequently used for identifying occupational training requirements, guiding human resource management, providing information for potential recruits, and coding, recording, and reporting occupational qualifications.

The CF underwent an initiative to modernize its occupational classification system through the MOSART project. It was initiated by HR(mil) with an objective to develop a military occupational structure that enhances the strategic capability of the CF to meet an increasing array of operational missions with highly skilled and motivated people, while expanding the range of career opportunities for CF personnel and maximising the efficiency of the CF Human Resources (HR) Management System. Due to the close link between MOSART and this project, a brief description of MOSART is provided.

Specifically, the MOSART project had three primary goals:

1. To establish a new occupational structure that enhances operational capabilities, is cost effective, and contributes to increased retention in the CF through the use of broader career fields;

2. To revise all supporting policies and procedures related to the military occupational structure; and

3. To create a master implementation plan that depicts the transition to the new structure across the CF.

To achieve these goals, MOSART adopted an evolutionary approach towards the required MOS modification, and started with an examination of the overall CF work requirement at the *job* level. Traditionally, the development of work requirements, as well as the process for reviewing and updating the MOS, has taken place using *occupations* as the basic building block. The use of the occupational model has essentially created a stove-pipe effect, and has necessitated the establishment and maintenance of separate and detailed occupational specifications for both the Regular Force and the Primary Reserve. Having recognized this problem, MOSART initially analyzed and defined the CF work at a job level. Jobs serve as the basic entities for managing CF personnel. Once jobs are identified and defined, decisions can be made on how to group similar jobs into larger constructs in the MOS, for example, occupations, sub-occupations, and career fields.

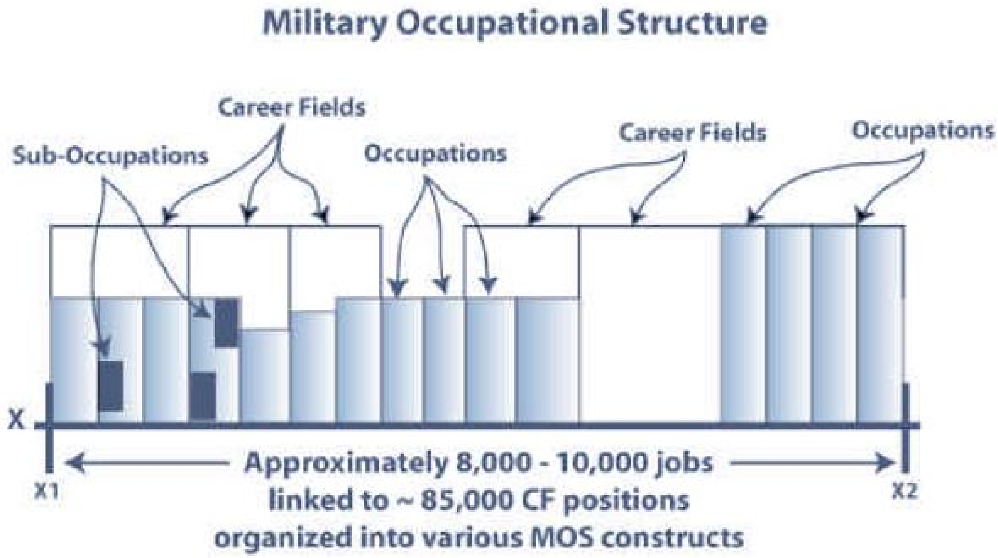

Figure 1: An illustration of the CF military occupational structure.

The MOSART project established a logical and sequential process to achieve the desired MOS structure, which included amending existing specifications with their inherent work requirements and their associated impacts on HR management areas. A modernized MOS makes it possible to transition the HR management system from the old position-based system to the new job-based system. Currently, the CF manages its work through approximately 85,000 positions. Following the principle of job-based management, these positions are consolidated into 8,000 to 10,000 military jobs based on their work requirements. This allows for a more effective and efficient way to manage personnel across the CF.

Another important endeavour in the MOSART project was the establishment of links between jobs and their competency requirements. This produces a robust system that allows the development of succession plans, career paths, and expeditious evaluation of CF members against their designated jobs. At the strategic level, this system assists in the development of integrated professional development strategies and plans. For the CF members, the system is more open and transparent, allowing them to gauge their personal qualifications and competencies against existing job inventories, thus providing a clearer picture of professional development requirements, personal goals, and in turn, more control and influence over individual careers.

During the process of defining the CF work domain, MOSART started with a high-level gap analysis to identify key discrepancies among CF strategic capabilities, force structure, and occupational specifications. A standardized web-based survey was used in job analysis for developing occupational specifications. Besides the existing tasks, skills and knowledge (TSK) inventory, competency measures were collected in the survey and incorporated into the job description. The re-grouped occupations were coded using a new five-digit MOSID, which replaced the three-digit MOC used in the old MOS.

Accompanying this change of the coding system, significant modification was also made within each occupational specification. In the context of this project, occupational specifications were the primary data source for the integration effort. When the project was conducted, MOSART had not completed the job analysis, therefore, the occupational specifications that were used in this project were provisional in nature. The analysis described in this report reflects our best knowledge obtained from the latest version of the occupational specifications at the time the study was performed.

As the second year of the project began, a MOS database (which we named for internal use "version 1/July 2006") was received. The new database adopted a new data structure, as a result, CAMA was updated accordingly. In addition, CAMA was modified to enhance its data searching and editing capability. A MOSID plug-in to IPME with an enhanced search capability was also developed during this phase.

While the database and application development were taking place, we also continued to work with the Canadian Forces Experimentation Centre (CFEC) and MOSART. Reports and data from the UAV Crew Selection study [2] were obtained from CFEC, and were later extensively leveraged in the follow-up validation study that took place in the final phase of the project.

This report is a summary of the validation effort. In the following sections, the report describes: the problem statements (Section 2), two software platforms (Section 3), typical modeling processes (Section 4), a UAV model created in both IPME and ISMAT (Sections 5 and 6, respectively), and a final summary of findings (Section 7).

2 Problem Statement

Alion Science and Technology (formerly Micro Analysis & Design, Inc.) began the development of IPME in 1995 with QinetiQ CHS. In 1998, DRDC Toronto joined the development program. Together with DRDC Toronto and QinetiQ, Alion designed this discrete-event simulation application to support human factors analyses, more specifically, to support examination of stressors on human performance. IPME focuses on the human, the tasks that the human performs in support of a goal, the environment in which the human operates, the stressors that affect human performance, and an interface with external simulations. A secondary goal of the development program is to offer modeling flexibility to the analyst. This is realized through plug-and-play component models, user-defined functions, performance shaping functions (PSFs), and a configurable master database.

Since development has focused on functionality and flexibility, built-in models packaged with IPME are minimal. IPME does not include actual data or populated PSFs, environment models, or operators. While the functionality is available for analysts to add customized data, the process can be time-consuming. A need was recognized to provide readily-available, built-in data to support model creation and analysis. In particular, two objectives were identified for IPME:

1. *Built-in data* to support model construction.

2. A simpler method for developing models in support of the *personnel and training domain*.

While it is possible to examine personnel characteristics and training aspects of a system using IPME, the job analysis is tedious because of the lack of built-in data. Operator occupational characteristics and training requirements are important aspects of system modeling; therefore, it is desirable to enhance direct support to these types of models in IPME.

The US Army has long recognized the importance of including training data when examining a system. The US Army MANPRINT program started in the mid-1980s with a goal of optimizing "*how well new systems work with soldiers in the field by including the soldier in the design process*" [7]. By examining how soldiers can perform their jobs with provided equipment and taking into account human characteristics such as aptitude and physical traits, combat readiness is increased. There are seven MANPRINT domains that are considered during the system acquisition process:

1. Personnel Capabilities: the cognitive and physical abilities of a soldier.

2. Manpower: the number of personnel required to operate, maintain, sustain, and provide training for systems [6].

3. Training: education required to provide personnel the knowledge and skills they need to perform their jobs.

4. Human Factors Engineering (HFE): the integration of human characteristics into system definition, design, development, and evaluation to optimize human-machine performance under operational conditions [6].

5. System Safety (SS): the variables that minimize the potential for system errors (human or machine).

6. Health Hazards (HH): the system variables that increase the risk of human injury or death.

7. Soldier Survivability (SSv): the system variables that reduce fratricide, detectability, and probability of being attacked [6], and minimize system damage and operator fatigue.

Many of the MANPRINT domains can be modeled in IPME via the component model structure. By incorporating the Canadian Air Force MOSID data in IPME, the analyst will be able to use the occupational specifications, training data and requirements in their models to examine operator performance and analyze system staffing.

MOSID data were reviewed and initially converted into a Microsoft Access database. CAMA was then created for managing this database. Its basic functions included MOS data viewing, key word searching, and data editing. CAMA's capability was later integrated into a MOSID plug-in that could be accessed from IPME, which enabled analysts to specify MOSIDs for operators in a crew model.

During the course of the project, the MOS database was upgraded several times, each associated with a change of its internal data structure. As a result, we updated CAMA and the IPME plug-in accordingly. Since the MOS data had a big impact on both application development and model construction, a detailed review of these data is provided in the next sub-section.

Table 3: Nine Occupations Initially Reviewed

Occupation	MOSID
Airborne electronic sensor operator	00019
Flight engineer	00021
Aviation systems technician	00135
Avionic systems technician	00136
Air navigator	00182

Aerospace control officer	00184
Aerospace engineering	00185
Airfield engineer	00189
Aerospace control operator	00337

2.1 Occupational Data and the Review Process

This section describes the available occupational data and the process used to review and interpret the data.

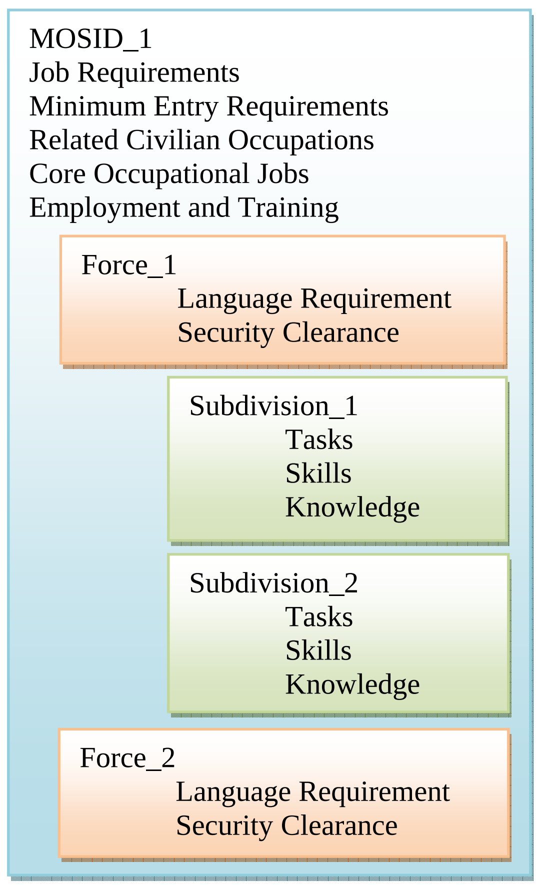

Figure 2: MOS Data Relationships based on the Initial Review of Occupational Specifications

Initially, the specifications for nine Canadian Air Force occupations (see Table 3) were reviewed to determine what data could be used in human performance models. These specifications were in Microsoft Word document format. They were reviewed multiple times by two analysts to

determine the data structures and relationships. The purpose was to import these data into a database and identify information elements that can be applied in a computational model. Generally speaking, an occupational specification contains information about job requirements, training needs, and career progression plans. Each occupation is typically classified into three different force types (Regular Force, Primary Reserve, and Special Force), each of which further consists of several subdivisions. Job tasks, skill requirements, and knowledge requirements are detailed at the subdivision level. Requirements filter down the hierarchy. For example, minimum entry requirements are applicable for all forces and subdivisions of any occupation. Security clearance and language requirements are specific to forces and their subdivisions. Figure 2 is a conceptual diagram that displays our initial interpretation of the hierarchical relationships in the MOS data.

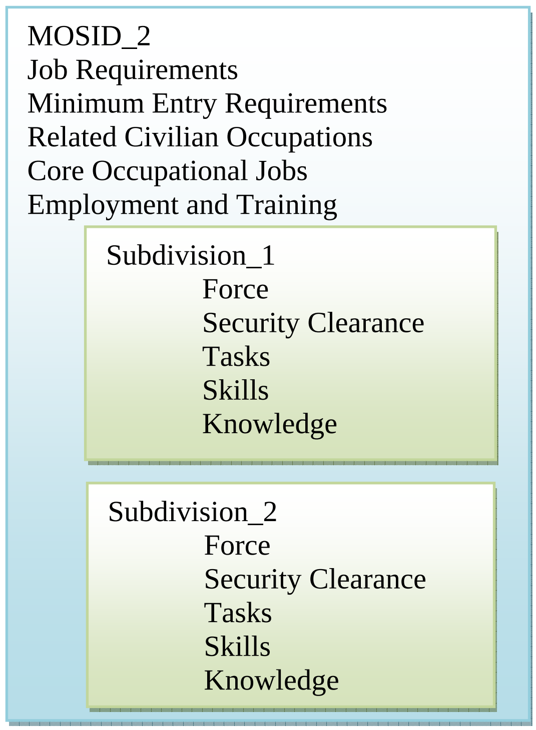

Figure 3: Updated MOSID Relationships

The second batch of MOS data was delivered to us in the form of four Microsoft Access databases. Compared with the occupational specification documents that we reviewed previously, these databases presented several challenges. First, the MOS structure in the new databases differed from the one in the specification documents. Specifically, the data hierarchy was reduced. Figure 3 illustrates the modified data relationships. Note that the force designation and security clearance information are now included in the subdivision (“Job”). Language requirements are specified as knowledge statements for a subdivision. Upon further examination of the database tables, we noticed that several data keys and enumerated type variables were assigned different values across the databases. This prevented us from following the original plan

to combine four databases into a single consolidated one. Although using a single database was desirable because it would simplify data management and information access, this artifact in data source forced us to choose an less-than-optimal solution. By presenting occupational data in separate databases (one for each occupation), analysts were limited to using the data from a single occupation at a time. The provisional nature of the source data caused functional and usability limitations. With the completion of MOSART, structural discrepencies across MOS data will be eliminated and we anticipate this issue will be resolved.

The database management tool, CAMA, was developed to access multiple MOS databases. It includes a user interface for specifying the data source. After an occupational database is selected, corresponding MOSIDs in this database are listed on the left-hand side (see Figure 4). In this example, after an air navigator occupation is selected (as highlighted in the left pane), its corresponding jobs are automatically shown on the right-hand side, which includes an air mobility navigator and a maritime tactical control officer (only these two jobs were populated with data when this study was conducted). More information about each job can be further revealed, including its duty and responsibility descriptions, working environment conditions, task, skill, and knowledge statements, and performance requirements.

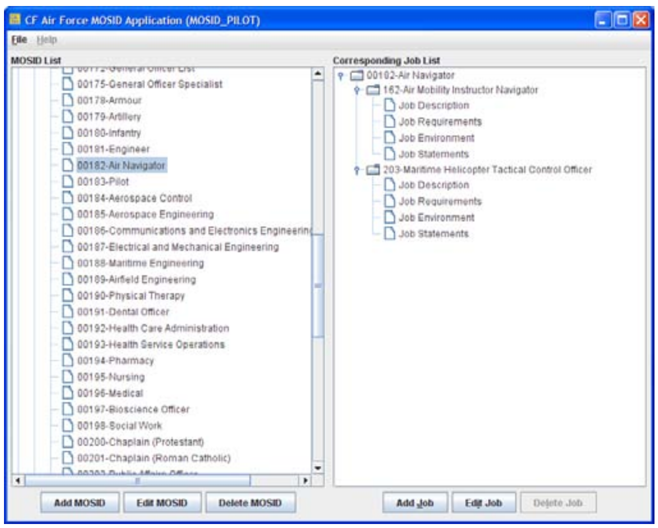

Figure 4: CAMA Main Dialogue

Some of the occupational data are textual descriptions, as shown in the following example for an air mobility instructor navigator (job 162 from the MOSID 00182 – Air Navigator) [5].

> *Environment:* “The Maritime Helicopter Instructor Navigator performs his tasks either on the ground or in the air in the CH-124 Sea King. On the ground, he will work in a classroom environment, a simulator or an office, normally located near the flight line. This job applies to Development Period 2.”
>
> *Physical Effort:* “The incumbent is engaged in heavy physical activities of various kinds. The physical effort required for lifting, pulling, and similar activities is considerable…”

Others have quantitative ratings, such as the task, skill, knowledge (TSK) requirements. For each occupation, its required TSKs are first specified in the form of statements. Each statement is then associated with a numerical rating obtained on a 5-point proficiency scale (see Table 6). Examples of a task and knowledge statement are shown inTable 4. Note that in the databases we obtained from MOSART, the skill statements were not populated for any of the jobs. This artifact forced us to use task and knowledge data in the following validation effort. However, it is expected that the skill data can be applied in an IPME model exactly the same way as the TK data, therefore, this artifact does not limit the generalizability of the validation effort.

Table 4: Sample Task and Knowledge Statements

Task Statement

Duty ID	**C – Navigation**
Serial	T0082
Statement	Program navigation system equipment
Proficiency Level	4

Knowledge Statement

Duty ID	**A – Air Traffic Control**
Serial	K0001
Statement	ATC Manual of Operations
Proficiency Level	2

Since only quantitative data can be used in a computational model, the next step in our analysis was to determine what data could be incorporated into IPME. Table 5 shows the typical structure of an occupational specification. Based on our analysis, we classified such a specification into three categories based on the information's relevancy to IPME modeling.

Category 1 (highlighted in red) refers to data that are irrelevant to a computational human performance model. Examples of such data are pay codes and occupational development plan.

Category 2 (highlighted in yellow) indicates data that are informative for a human performance model, however, their current form does not support a direct linkage to IPME modeling. Specifically, these data are mostly textual descriptors and consists of descriptions of working conditions, physical and mental efforts. The lack of numerical representation makes it difficult to incorporate the data directly in an IPME model.

On the other hand, these data do provide analysts with information about the nature of work in which operators typically engage. They can be used indirectly in IPME to, for example, support the identification of environmental stressors or the formulation of performance shaping functions. Consequently, we allowed analysts to access these data through the MOSID plug-in and left it as the analysts' responsibility to develop numerical relations for these data in an IPME model.

Category 3 (highlighted in green) represents data that can be directly applied in IPME models. More specifically, these are task, skill, and knowledge (TSK) statements, and their associated profeciency requirement scores. Together, they represent characteristics that military members have acquired through their professional training. The task statements describe the activities in which an operator from a particular trade is likely to engage, and a numerical score is provided

for each task statement to indicate the required performance level. Similarly, knowledge and skills required to conduct these tasks are specified in KS statements and a rating score is provided on the same proficiency scale (see Table 6). The numerical nature of the proficiency requirement score makes the TSK our primary target for this integration effort.

Table 5: A Structural Breakdown of a Typical Occupational Specification

Occupational Specification		
Section 1: General	Section 2: Occupational Development	Section 3: Occupational Performance Requirements
Sub-divisions	NCM Development	Qualification Levels
Occupational Specialty Specification	Occupational Development	Duty Areas and Task Statements
Job Requirements	Occupational Qualification and Progression	Skill and Knowledge Statements
Additional Performance Requirements	Operationally Functional Point	Performance Requirement Matrix
Comprehension and Judgment	Employment and Training	
Occupational Training and Experience	Core Occupational Jobs	
Working Conditions	Integrated Operational Framework	
Responsibility		
Resources		
Services		
Consequences of Error		
Environment		
Hazards		
Job Effort		
Physical Effort		
Mental Effort		
Analysis Effort		
Special Requirements		
Medical Standards	Modeling essential	
Language		
Security Clearance	Informational	
Pay Code	Irrelevant	

Table 6: Proficiency scale used for rating Task, Skill, and Knowledge (TSK) statements:

LEVEL	TASK/SKILL	KNOWLEDGE
1	the level of proficiency required to perform parts or elements of duties and tasks under continuous supervision	an awareness of the basic definitions and concepts associated with a topic or a body of knowledge
2	the level of proficiency normally required to perform duties and tasks under normal supervision	the level of understanding of definitions and basic concepts which enables the relating of this knowledge to job requirements
3	the level of proficiency required to independently and safely perform duties and tasks	the level of understanding of theory and principles of a topic or body of knowledge that is usually gained through formal training and job experience and which enables critical thought and independent performance
4	the level of proficiency which usually can be acquired by considerable training and extensive practical job experience	the level of knowledge which is gained from formal training and education and considerable job experience. This knowledge enables the synthesis/integration of theory facts and practical lessons learned to support the identification of solutions to non-routine problems
5	the level of proficiency indicated by a mastery of techniques and expert application of procedures	a recognized level of expertise, which includes a mastery of theory and application, related to a given body of knowledge

There are two potential ways to apply TSK data in an IPME simulation model. Firstly, the crew model, where operators are defined, allows an analyst to specify a military occupation for each operator by selecting the appropriate occupational code from the MOS database. Once an occupation is specified, the relevant skills and knowledge statements, together with their proficiency requirements, can automatically populate the occupational traits in the operator model. Figure 5 shows the dialogue in IPME with the knowledge statement “ATC Manual of Operations” selected. A trait representing that knowledge statement is created, and the trait mean value is set to the proficiency value of the knowledge statement. Knowledge statements are added to IPME as traits because IPME traits can be sampled from a selected distribution. In this case, sampled traits could represent varying degrees of operator proficiency.

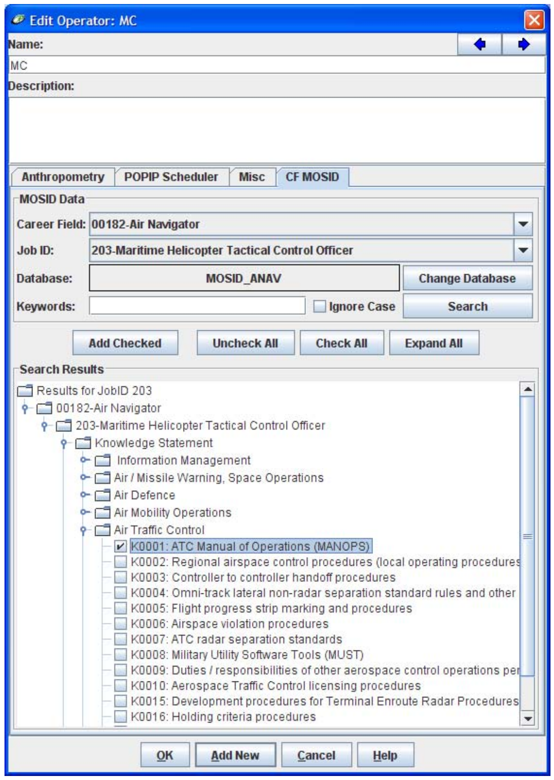

Figure 5: Adding MOSID Data to an IPME operator

Secondly, the task statements are integrated into the IPME task network models via a modification of the task definition, which allows analysts to connect a particular human activity to one or more task statements defined in the occupational specifications. This connection is accomplished by categorising the activity into a relevant duty area, then selecting the most representative task statements and their associated performance requirements.

After the task has been assigned to a particular operator, it is possible to compare the list of required task statements (TS_{req}) to the list of task statements described in operator's occupational specification (TS_{op}). A job similarity index (JSI) can be calculated by comparing the level of matching between TS_{req} and $TS_{op.}$ A JSI score of one means that the designated operator possesses all the skills and knowledge that are required by the operational tasks; whereas a score of zero represents the opposite extreme where the operator has none of the required skills and knowledge. Such an index is typically used in cross-occupation comparisons. One assumption is that the occupation that produces a higher JSI score better satisfies the job requirements, and therefore superior work performance can be achieved by assigning an operator from this occupation to the task. For more information about JSI and its application, see [2].

3 Introduction to IPME and ISMAT

The intent of this validation effort was to apply the newly developed IPME capability, create simulation models that utilize occupational data, and examine the model's sensitivity to these occupational characteristics. Since the US Army's IMPRINT software implemented similar functionality, the original project plan was to compare these two modeling packages. However, because IMPRINT was unavailable due to US export restrictions, ISMAT was used as a replacement. This has several implications, the most significant of which is that ISMAT consists of occupational data from the US Navy, and because of the significant difference between the Air Force and Navy occupations, it is difficult to directly compare model outputs from ISMAT and IPME. Since ISMAT adopts a drastically different approach for representing and utilizing occupational traits, it was decided to focus on comparing the modeling methodologies. A brief introduction to these two modeling packages is provided in this section.

3.1 IPME

IPME is an integrated modeling environment for representing human activities and analyzing system performance. An IPME model is organized as a system, which is a collection of models and data that represent human operators, their tasks, and the operational environment. A system is comprised of component models, including environment, crew, performance shaping functions, task network models, and a measurement suite. Operator activities are mapped out in a network of tasks (i.e., a task network model). The operators' characteristics, such as physical properties (e.g., weight, height), traits (e.g., fitness, training), and states (e.g., boredom, hunger) are represented in a crew model. The environmental stressors, e.g., physical conditions, crew, mission, or threat factors, are captured in an environment model. The impact of stressors on system performance is defined in a performance shaping function (PSF) model. The measurement suite supports comprehensive data collection.

IPME provides a graphical interface for describing system processes in a task network model. The task network model contains tasks and linkages between those tasks. Tasks generally denote human activities, but can also be used to support the simulation. An operator task contains timing information, conditions for execution, and operator assignments. Operators from the crew model may be statically assigned to particular tasks, or they may be dynamically assigned to tasks based on operator availability, aptitude, or other user-defined criteria. Logical expressions can be defined inside a task for manipulating the system state while a model is executed. Resources can be specified for operator tasks which are used by IPME's internal algorithm for predicting the operator's workload. The linkages between those tasks represent system processes.

While it is optional to use the environment, crew, and PSF models, using all three in combination with the task network model takes advantage of the component models' plug-and-play feature. For example, different crew models can be combined with a single task network model to allow an analyst to examine how different operators would perform the same set of tasks. The relationship between these component models is shown in Figure 6.

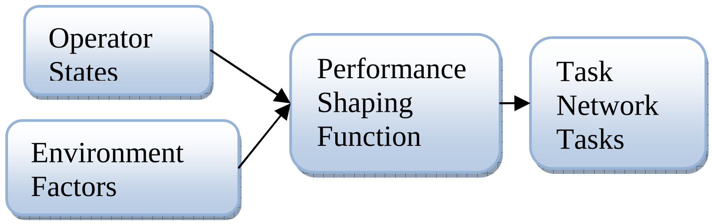

Figure 6: Component Model Relationship

In addition, IPME allows analysts to create a measurement suite, which provides a simple method for defining an experiment and modifying system variables in a structured manner. For example, a measurement suite can be used to sample operator traits and anthropometry values from different distributions across simulation runs.

In this project, IPME was further developed to include a plug-in for easy incorporaton of job-related data from the MOS database. A tab was added to the operator definition interface in the crew model to allow users to filter and select information from the database. This enables analysts to choose specific job-related data and incorporate that data into a model as operator characteristics. A sample screenshot of the modified interface is shown in Figure 7.

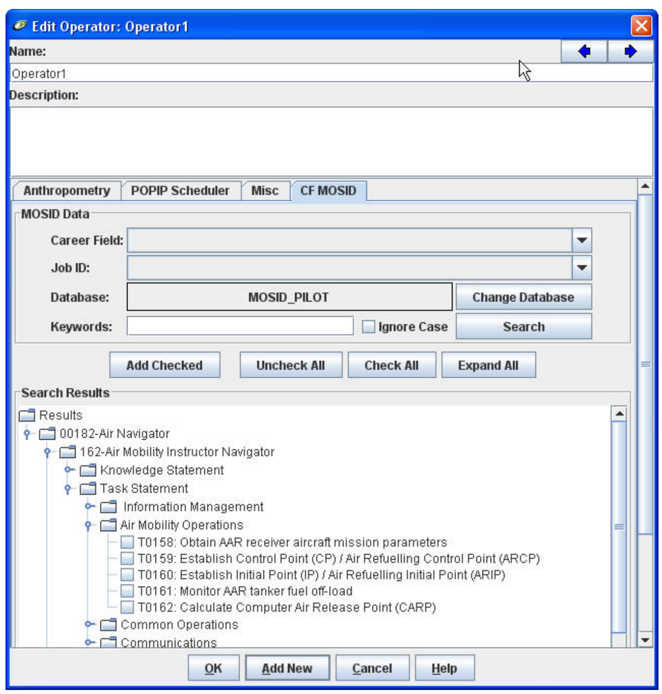

Figure 7: Edit Operator Dialog

As part of this project, CAMA was created as a companion tool to support the use of occupational data IPME. It provides a graphical interface for analysts to view, modify, and search the MOS data. In CAMA, occupational data from different MOS databases can be viewed in a hierarchical structure. The hierarchy reflects the relationships between occupational fields and jobs. When an

occupation (e.g., a MOSID) is selected, the corresponding jobs are automatically ordered and listed (as shown previously in Figure 4). Data can be modified for each occupation or job. Figure 8, as an example, is the interface for modifying the basic occupational definition. In order to prevent accidental modification, the data are presented to the user in read-only format. The user must click a button before changes can be made to the database.

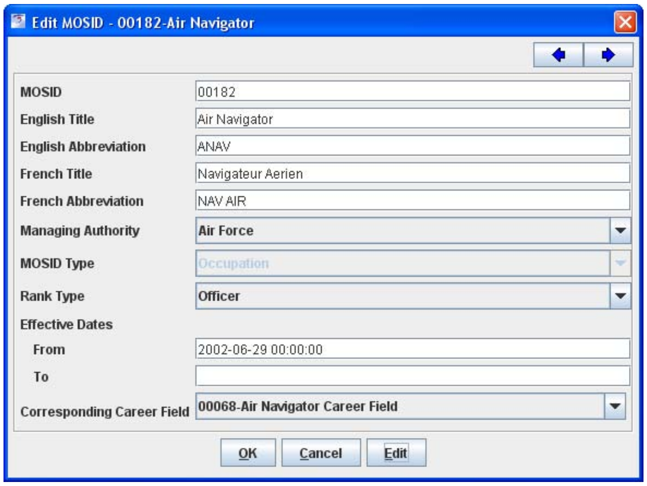

Figure 8: Interface for Modifying the Basic Occupational Definition

At the job level, data are entered on a series of tabbed dialogs, as shown in Figure 9. Details regarding the job description, environment, requirements and task, skill and knowledge statements can be modified on the tabbed dialogs. Such edits are immediately stored in the MOS database.

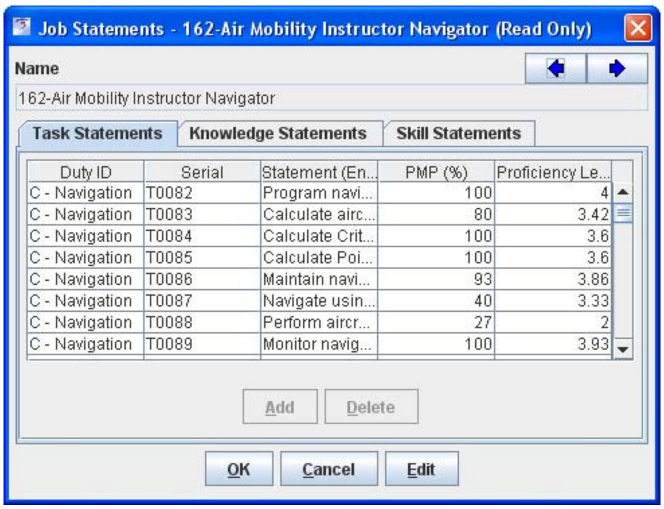

Figure 9: Job-related Data

CAMA supports keyword searches. This provides analysts a quick way to navigate through a large amount of occupational data and to, for example, identify occupations that possess certain

skill sets. Search feedback is presented in a hierarchical arrangement with the lowest level showing the context of the keyword. An analyst can then double click each feedback entry and the relevant information from that location in the database will be presented. Sample results from a keyword search are shown in Figure 10.

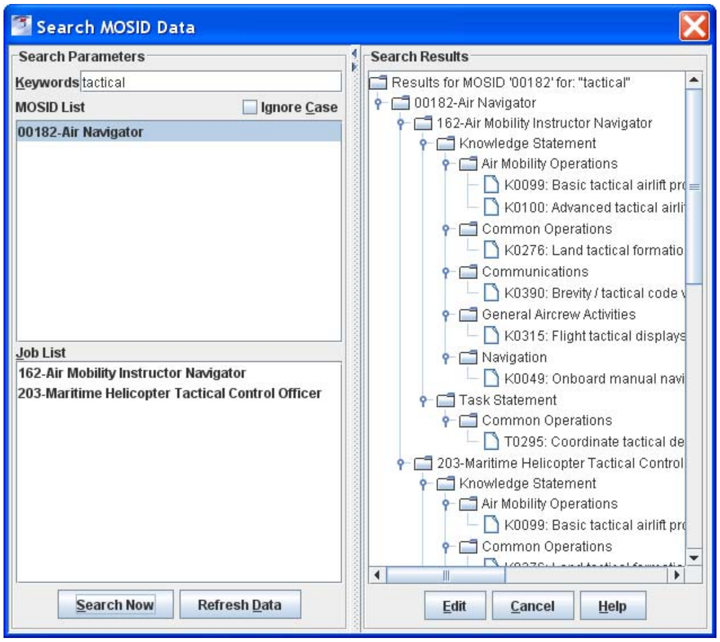

Figure 10: Sample Keyword Search Results in CAMA

3.2 ISMAT

ISMAT was developed under a Small Business Innovative Research (SBIR) project entitled Human Systems Integration (HSI) Rapid Analysis Tool for Evaluation of System Concepts Early in Development, and was sponsored by the Naval Surface Warfare Center-Dahlgren Division (NSWC-DD).

ISMAT was created to support planning, designing, and, most importantly, evaluating alternative manning and automation concepts prior to implementing technology, with the goal of reducing crew sizes, workload, or cost. This tool is designed to be used by analysts to evaluate operator workload and cost for different manning options. More specifically, ISMAT has the following capabilities:

- Allocate functions and tasks to humans and technologies;
- Identify additional training requirements resulting from the introduction of new technologies; and
- Predict relative costs.

ISMAT incorporates task characteristics (including task timelines) and operator knowledge, skills and abilities (KSAs) into a dynamic human performance simulation framework. Consequences of different task allocations can be observed and quantitatively studied in the form of cost analyses,

crew size requirements specification, and operator workload reports. Of great interest to this project, ISMAT supports the examination of operator skill sets that are required to perform specific tasks. Based on such analysis, operator knowledge and skill gaps can be identified.

In particular, ISMAT contains an internal library that consists of specialized job-related information (e.g., skills and proficiency levels) from the US Navy's personnel inventory. A generic human skill taxonomy is included in ISMAT. This taxonomy is based on [3] and it consists of fifty different skills and abilities grouped into eight categories, as shown in Figure 11. This taxonomy was adopted because its scales are anchored with behavioral examples.

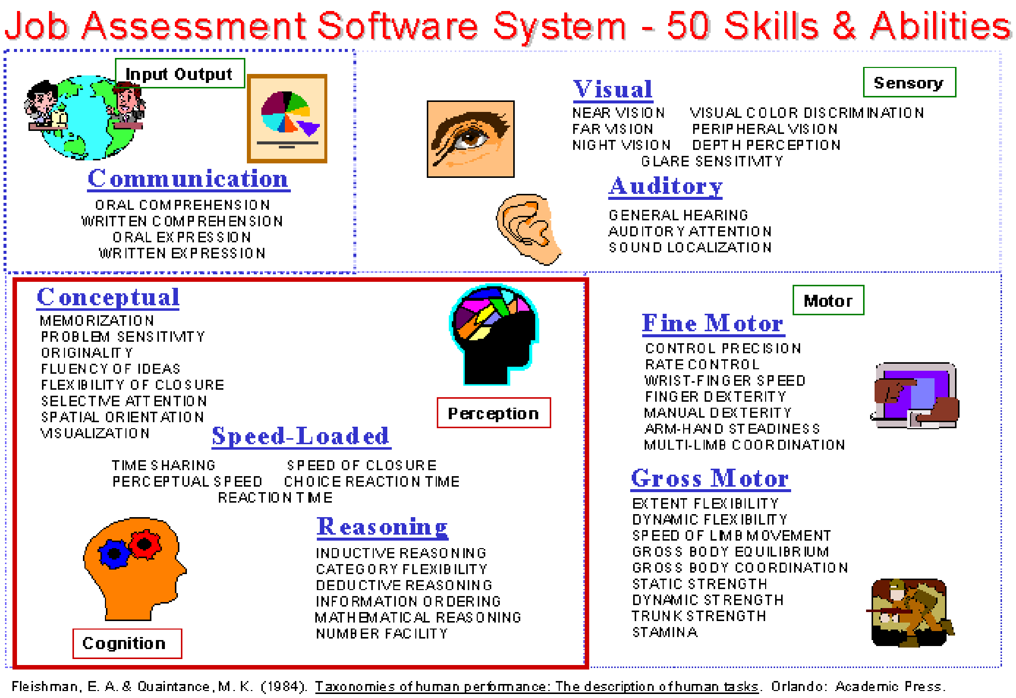

Figure 11: Fleishman Human Skill Taxonomy

Based on the Micro Saint Sharp simulation engine, ISMAT allows analysts to study the probabilistic behavior of a simulation model for assessing the interaction between crewmembers and assigned functions or tasks under the context of various operational scenarios. The common parameters required to run an ISMAT model include crew definition, maintenance actions, and scenario definition.

Crew definition is achieved by adding operators to a model. Operators are created either automatically by importing pre-defined crew documents or manually by selecting them from a library.

Scenario definition involves the addition of specific functions and tasks that the operators perform. ISMAT functions are structurally equivalent to IPME networks, however, significant differences exist between them. Unlike IPME networks, ISMAT functions are scheduled on a timeline and are not required to be decomposed into tasks. Before executing an ISMAT model, the analyst must specify one of three goals (i.e., minimize cost, minimize workload, or minimize

crew size) for guiding model behavior. During model execution, ISMAT attempts to allocate functions and tasks to operators that best meet the selected goal.

Overall, ISMAT is a flexible modeling platform which allows analysts to use simulation to address personnel related ‘what-if’ questions. A typical application of an ISMAT model includes assessing the impact of crew reduction and alternative task-operator assignments.

4 Validation Objectives and Methodology

4.1 Objectives

With access to occupational data, analysts can represent Canadian Air Force personnel more precisely with the addition of knowledge and skill attributes in a crew model. It is now possible to create IPME models that are sensitive to these occupational characteristics, and allow analysts to investigate research questions related to manning requirements. Possible research questions include:

1. What kind of skills and knowledge are required by an operator (or a group of operators) to perform a designated job?

2. How will changes of operator occupations affect system/task performance?

3. What kind of training is required for an operator to satisfy job requirements?

4. How should skills and knowledge be prioritized based on their criticality in support of job performance at a prescribed level?

The objective of this study was to verify and validate the newly developed capability in IPME and demonstrate the utilization of occupational data in human performance models to address such research questions.

4.2 Methodology

The generic human performance modeling process is well established. With the addition of occupational data into modeling tools, it is possible to use these data for addressing manning and training related questions. From a modeler's perspective, one critical modeling issue is the association of occupational traits with operator job performance. In IPME, a possible solution is to use performance shaping functions (PSFs) to create a performance degradation (or improvement) formula in which the impact of occupational traits on performance can be specified. However, this requires sufficient empirical evidence to justify the validity of the PSFs. Pragmatically, evidence of this kind is difficult to obtain, and existing data may not generalize to different task domains. Therefore, we decided to explore an alternative approach by adopting a Job Similarity Index (JSI) to predict the level of match between operators with specific skill sets and their designated tasks.

Originally proposed by [2], the JSI is the ratio of the number of task and knowledge (TK) statements required by a task and the number of those required statements satisfied by an operator. An operator must meet two criteria to satisfy a TK requirement: first, the operator's occupational data (obtained from the MOS data) contains the TK statement required by the designated task; second, this operator's proficiency level for this TK exceeds the level required by the task. A JSI score is calculated by dividing the number of satisfied TK statements by the total number of TK statements required by this task. For example, if an identification task requires fifteen distinct TKs and an air navigator operator satisfies ten of them, then the air navigator's JSI

for this task is computed as 10/15 = 0.66. A JSI of 1 indicates that an occupation fully satisfies the task's requirements, although the operator may possess additional "unused" TKs, which reflects a case of overqualification.

Farrell et al. hypothesized that "a person who has a high JSI will perform well in a new job with minimal training, since they already perform most of the tasks and have most of the knowledge required for the new job"[2]. This rationale was used in our study and JSI scores were computed for the IPME model. However, since ISMAT has no internal constructs for representing TK statements, JSIs were not collected for the ISMAT model. Other conventional ISMAT metrics, such as task completion times and operator level of effort were used as performance indicators.

In this study, UAV operation models were created. The objective was to identify, among existing Air Force occupations, the best occupations to be assigned to three operator roles. Since we did not have a complete Air Force MOS database, the practical goal was to examine the use of MOS data in simulation models for supporting such type of analysis.

A UAV operation scenario, created in a previous project for investigating adaptive and intelligent interface design [4], was re-used in this study. The scenario is one hour long and consists of three segments, each with a twenty-minute duration. It begins with a fictitious advanced security briefing to Commonwealth Heads of Government Meeting (CHOGM) security staff, conducted in February 2011. A probable terrorist threat is located in a boat off the coast of Newfoundland. The first segment is considered low workload because the three-person UAV crew controls only a single Vertical Take-off UAV (VTUAV), which is previously launched from a Canadian Patrol Frigate (CP-140), on a regular surveillance mission. Following initial system check-out, the VTUAV is required to approach and record video on one potential terrorist trawler (designated Contact 2), which at the time is conducting normal fishing activities.

In the second segment, the crew workload increases. The CP-140 crew starts a second UAV (a Mini UAV) which is also managed by the three-person UAV crew. The Mini UAV monitors a trawler that is fishing illegally. At approximately the same time, the VTUAV is tasked to search for a new target, the location of which is initially not certain. The UAV crew has to identify this target among three boats. At the request of the UAV crew, a third UAV is deployed. Together with the VTUAV, the crew uses two UAVs to image these boats. At the end of the second segment, only the third boat is yet to be investigated.

The last segment begins with the crew losing contact with the VTUAV. In response, the CP-140 launches three Mini UAVs to monitor the third boat. At the same time, two CF-18s are tasked to close on the area. Boat #3 is identified as a terrorist vessel. It launches a Lethal UAV which is armed with a "dirty" bomb and is flying towards St. John's. The UAV crew needs to decide proper counter-measures. The scenario concludes at 60 minutes as the CP-140 leaves the area to search for the Lethal UAV that has been launched. For the UAV crew, the last segment represents a high workload scenario due to multiple UAVs they are monitoring and time-sensitive decisions that are made.

Annex A describes the scenario in more detail. For complete information, readers are refered to [4].

This contrived UAV mission was modeled in both IPME and ISMAT. The research question was to identify adequate occupational requirements for the UAV crew. In this case, the crew consists of three operators: a mission commander (MC), a payload operator (PO), and a vehicle operator (VO). These operators were represented in both IPME and ISMAT models. Various occupational traits were assigned to the operators and model outputs were collected to identify the best-qualified occupation to fulfill each of these three roles.

Due to a lack of direct access to subject matter experts, there were not sufficient data to create a UAV model from scratch. A decision was made to leverage other UAV-related projects, specifically, a UAV operator selection study [2] and multiple UAV performance models [4]. Data presented in these two projects were re-used in the current study for constructing IPME and ISMAT models. In addition, since access to the complete Canadian Air Force occupational data was not available at the time the study was conducted, only selected occupations from the existing MOS database were examined in the IPME model. Similarly, because ISMAT contained only US Naval occupational data, the model could only examine UAV operator selections from those naval occupations. Due to these limitations, outputs from IPME and ISMAT models could not be compared directly. However, a contrast between two modeling processes, especially their different approaches on applying occupational data, provides insights on future modeling to support personnel and crewing issues.

5 IPME Model

This section describes the IPME UAV model that was created for this validation study. Section 5.1 explains the process used to create the model. Section 5.2 describes the model itself.

5.1 Modeling Process

5.1.1 Available Data Sources

The data for constructing this UAV model came from the following sources.

1. CFEC Project Report on the Alternative Crew Selection Method [2]
2. Hierarchical Goal Analysis and Performance Modeling for the Control of Multiple UAVs/UCAVs from an Airborne Platform [4]
3. CMC's IPME models
4. MOS databases
5. CFEC project database

Since most of these data were generated in former projects and for different research purposes, it was a challenge to integrate and re-use them in a single model. To construct a UAV model, we extracted pieces of information from these sources as required by IPME. Table 7 displays the type of information that was obtained from each source and the corresponding parameters in the IPME model.

Note that the process involved in populating this UAV model is not typical in IPME modeling. It represents a work-around solution in response to the lack of access to subject matter experts which was encountered in this study.

Table 7: Sources for IPME UAV Model

Model Input	CFEC Project Report on the Alternative Crew Selection Method	Hierarchical Goal Analysis and Performance Modeling for the Control of Multiple UAVs/UCAVs from an Airborne Platform	MOS Databases	CFEC Project Database	CMC IPME Models
Task List	X				
Assigned Operator	X				
Mean Time		X			X

Standard Deviation					X
Task Sequence		X			X
Task, Skill and Knowledge Statements for Goals				X	
Goal ID		X			
Task, Skill and Knowledge Statements for Operators			X		

5.1.2 Determining Relevant Tasks and Task Sequence

Once data sources were determined, the next step was to identify the relevant mission scenario and, accordingly, the task sequence that the UAV crew needs to perform.

Three actions were taken: firstly, execute existing IPME UAV models produced by CMC Electronics (these models are described in [4] and referred as the CMC's models in the rest of the report); secondly, convert CMC's models to a newer IPME format; and thirdly, map the task identifiers used in the CMC models to goals from the CFEC Project Report [2].

Since the task networks included in CMC's models were based on a specific mission scenario adopted in that project, they could not be reused in their original form for this study. However, they did provide useful information for determining the task order. In this study, we first reviewed the goal hierarchy recorded in the CFEC Project Report [2] and then derived UAV operator's task sequence based on task order information in CMC's models.

Three CMC models were originally created in IPME version 3 and stored as DAT files. This file format is no longer supported by the latest version of IPME (i.e., version 4), so the files had to be converted to a newer format to facilitate analysis. A three-step translation scheme was followed.

1. the DAT files were loaded into IPME version 3 and then exported in an XML file format (i.e., SYX). The SYX data format is supported by the latest version of IPME (i.e., v4);

2. when the SYX files were loaded into IPME v4, the model expressions were automatically translated into the newer syntax used in IPME version 4;

3. after the conversion was completed for all three DAT files, they were aggregated into a single project file (i.e., XML file format that contains multiple systems).

This process is illustrated in Figure 12.

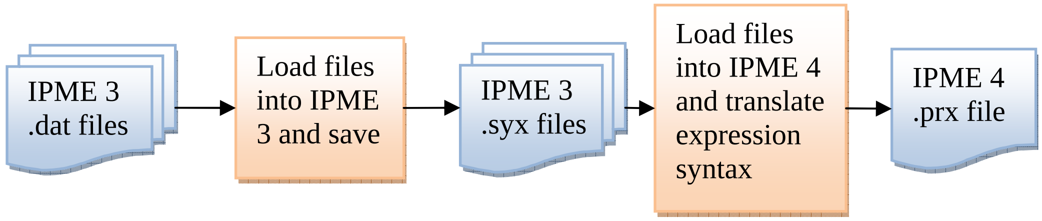

Figure 12: UAV Model Data Files Conversion Process

In CMC's original models, the operational sequence diagram (OSD) identifiers were used to label tasks. Since these OSD IDs were numerical numbers, it caused difficultly in interpreting task sequences. To address this issue, a four-step process was taken to convert the OSD ID-based task names into meaningful textual descriptors, and also to identify tasks that could be re-used in the new model. This process is illustrated in

Figure 13.

1. Starting with the Goal IDs obtained from [2], we located the corresponding OSD IDs in the Hierarchical Goal Analysis (HGA) output contained in Annex C of [4].

2. We then searched the project file that contained three CMC models for task names with identical OSD IDs. This produced a lsit of task IDs.

3. The same OSD ID was then located in the OSD diagrams (from the Annex D of [4]) to identify the corresponding Goal ID.

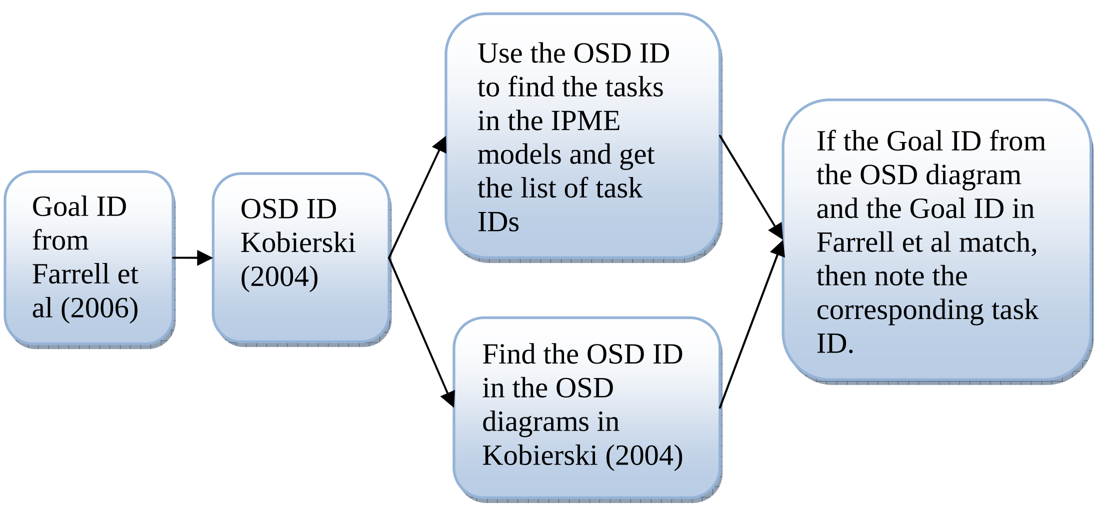

Figure 13: Steps Taken to Match Goal IDs, OSD IDs, and Task IDs

4. The OSD diagrams listed a node name and a Goal ID for each OSD ID. When the Goal ID in the OSD diagram matched the Goal ID obtained from [2] (i.e., step 1), the IPME task ID was recorded as the corresponding task ID for that goal ID. These tasks were regarded as tasks-of-interest for this study, and were re-used to construct the new UAV model.

After all re-useable IPME tasks were identified, the CMC models were run in IPME (version 3.0.26) to collect its execution trace files. The re-useable tasks were then located in the trace files. Based on their order in the trace files, new task sequences were then obtained for constructing the new UAV model for this project.

Basic task parameters for the new model, such as task mean times and standard deviations, were directly re-used from the CMC models. [4] provides such information for most of the modeled tasks.

Table 8 shows a portion of the result from this mapping process. A complete conversion table is available in Annex B.

Table 8: Illustration of the Mapping between Goal IDs, OSD IDs, and Task IDs

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID
2.1.1 radar plot of an area of interest is current	4-9	164 166 167	TN TN UP	2 2 3	2 2 7	21.12.11 21.12.12 27.6.5
3.5.2 a determination of the SAC (OSC) is completed	12	196	TN	3	10	27.12.3
3.5.1 command & control of tactical situation is assessed	12	192	TN	3	10	27.12.1

5.1.3 Identifying Task and Knowledge (TK) Statements based on Task Goals

After a new task network for the UAV model was completed, the next step was to generate a list of task and knowledge statements for each task. These statements represented the TKs required by these tasks and were derived based on the goals associated with each task.

The following list of data were produced by this process:

1. A list of duty areas, including their names and codes;
2. A list of TK statements associated with each goal ID; and
3. A unique list of the names of each TK statement used in the model.

Once we had a set of goals, we proceeded to identify the TK statements for each goal. After obtaining permission to use a CFEC project database (i.e., Data source 5), a query was performed to retrieve a complete list of the TK statements required for each goal. Note that some of the goals included in this query were not included in the IPME 4 UAV model because there were no corresponding tasks in the CMC IPME models. The goal data for goals not included were ignored.

Next, character replacements were performed on the list of TK statements to ensure the statements conformed to IPME naming restrictions. The following replacements were made in the listed order.

1. Replace all characters except `&`, `/`, letters (a-z, A-Z), and digits (0-9) with a space (e.g., " ").
2. Replace `&` with the string " `and` " (note the whitespace surrounding the word).
3. Replace `/` and spaces (" ") with underscores (e.g., "`_`").
4. Replace any sequence of two or more underscores with a single underscore.

A list of unique statements was generated using the sort and filter features of Microsoft Excel. Minor capitalization corrections were made to the resulting list. This process produced a list of unique TK statements.

The CFEC database categorized each statement into a duty area identified by a single letter label (i.e., A-Z). However, duty areas in CAMA were identified by a textual descriptor. A translation of the duty area letter labels to the textual descriptions was required. Each task statement was located in the CAMA databases and all matching duty areas were retrieved (a single statement can belong to multiple duty areas). The duty area descriptor that had the most occurrences was assumed to be the duty area name which corresponded to the letter of the task statement. The result of this matching process is shown in Table 9.

For duty areas N, S, V, Y, and Z, no matches were found in any of the CAMA databases, so no duty area name suggestion could be made.

5.1.4 Phase 1: Evaluate Performance of Candidate Operators

The first step in building an IPME model was to define the UAV operator tasks. Such tasks were based on information obtained from the experiment described in the CFEC Project Report [2].

These tasks were performed by three UAV operators: a mission commander (MC), a payload operator (PO), and a vehicle operator (VO).

Table 9: Duty Area Labels and Names

Duty Area Label	Duty Area Name
A	Air Traffic Control
B	Air Defence
C	Navigation
D	Maritime Operations
E	Air Duties
F	Search and Rescue Operations
G	Air Missile Warning Space Operations
H	Common Operations
I	General Aircrew Activities
J	Mission Flight Planning
K	Electronic Warfare
L	Communications
M	Maintenance Duties
N	N/A
O	Tactical Level HQ Operations
P	Operational Strategic Level HQ Operations
Q	Mission Support Activities
R	Surveillance
S	N/A
T	Policy Framework and Organisational Structures
U	Information Management
V	N/A
W	General Military Requirements
Y	N/A
Z	N/A

Currently there are no specific Air Force occupations defined to serve these roles. The CFEC study [2] identified tasks requirements for each of these roles based on an analysis of their operational requirements. This information was re-used to populate the IPME task network.

The next step was to define three operators (i.e., MC, PO, and VO) in the IPME crew model. Traits (shown in Figure 14) were added to each operator that represented the knowledge and skills each operator possessed to perform the predicted MC, VO, and PO job elements. After the crew model was completed, each operator task in the task network model was statically assigned to one operator based on information in [2]. By using a static operator assignment, the assumption was that the selected operator would always perform the designated task. After the operators were defined and populated, the crew model was saved to the master database for re-use in Phase 2.

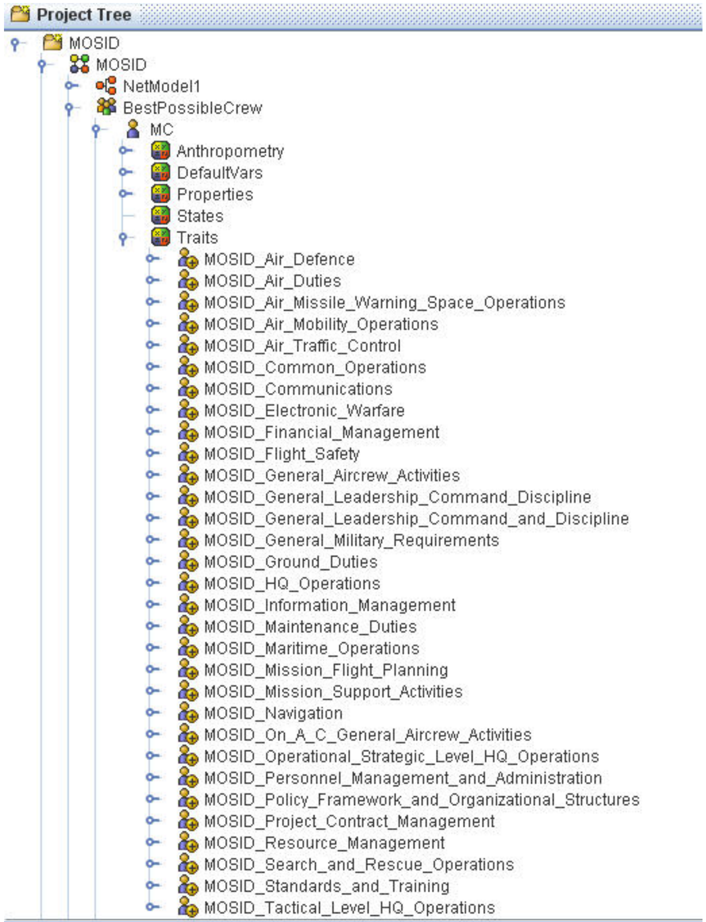

Figure 14: Operator Traits

Next, a candidate occupation, such as “Air Navigator,” was specified for each of the emerging jobs. The associated task and skill proficiency levels were then populated in the operator model. Logic was added in each IPME task to calculate the Job Similarity Index (JSI) for the assigned operator. For example, a JSI could be calculated for the “Air Navigator” performing a task in the role of a mission commander (MC). The TK statements possessed by the operator were compared to the TK statement required by a particular task. A ‘match’ was confirmed when the operator possessed the required TK statement and the operator’s proficiency level met or exceeded the task’s minimum proficiency requirement. If no minimum proficiency level was specified for the task’s TK statement, any operator proficiency level for that TK statement was considered a match. The total number of “matches” was divided by the total number of TK statements required by the task to determine the JSI for the operator-task pair.

A default minimum proficiency level of 3 was initially defined for all TK statements. This value was selected because it is near the average of all proficiency values in the database. This default value can be changed manually in the modeling process.

5.1.5 Phase 2: Identify Additional Candidate Occupations

After the task network, crew model, and data collection snapshots were created, alternative crew options were examined by substituting crew models containing alternate candidate occupations. These crew options were represented by crew models inserted into the IPME system using IPME's plug-and-play capability. The process involved the following steps.

1. An alternative candidate occupation was identified for each of three modeled operators.

2. A new, unassigned crew model was added to the IPME project. This crew model was populated by linking to the operators saved to the master database in Phase 1.

3. The modeler repeated the process described in Phase 1 for the second set of candidate occupations.

4. Using the plug-and-play capability of IPME, the task network model was executed again with a different crew model.

The development process in both phases was conducted iteratively. The model was tested and executed repeatedly, with the intent to provide a model that could be re-used and minimize the risk associated with obtaining data from external sources.

5.2 IPME Model

The top-level task network of the UAV model, shown in Figure 15, contained three sub-networks ("65 Model1", "66 Model2", and "67 Model3"), each representing a distinct CMC model, a data collection task ("73 Snapshot Task"), a task that parses the text files used to populate necessary arrays ("72 ParseTextFiles"), and some continuous tasks called by multiple sub-networks ("68 7.3.3.3 CONT Mini UAV" and "69 7.3.5.10 CONT EO").

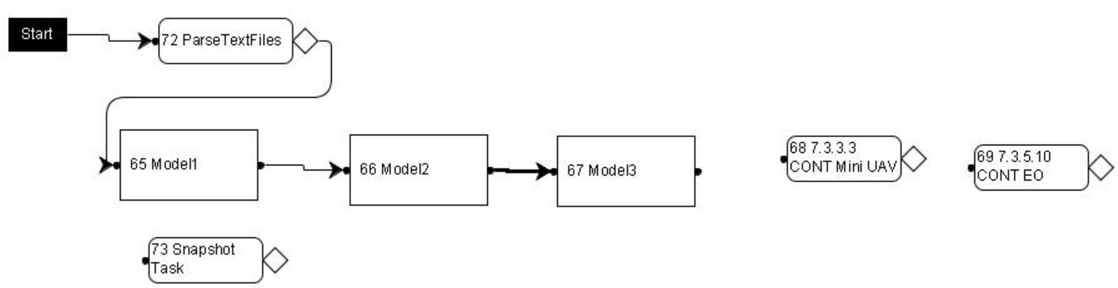

Figure 15: Top Level Network

In each network, there are smaller groups of tasks connected by paths. The first task in each group is given a name similar to "4.1.14." This number refers to the matching sub-network in the corresponding CMC model. For example, all tasks that follow "4.1.14" were in the 4.1.14 sub-network in the CMC model. The first task in each group is not assigned to an operator and does not take any time (i.e., task mean time equals zero). All other tasks are given names that indicate their goal id, e.g., "10.1.2.1 MC workstation is configured." These tasks are assigned to operators

and consume time. The last task in a task sequence calls a function that determines which task sequence to start next. The purpose of using such a function for connecting task branches was to improve the readability of the task network model and provide an easy approach for modifying the task execution order.

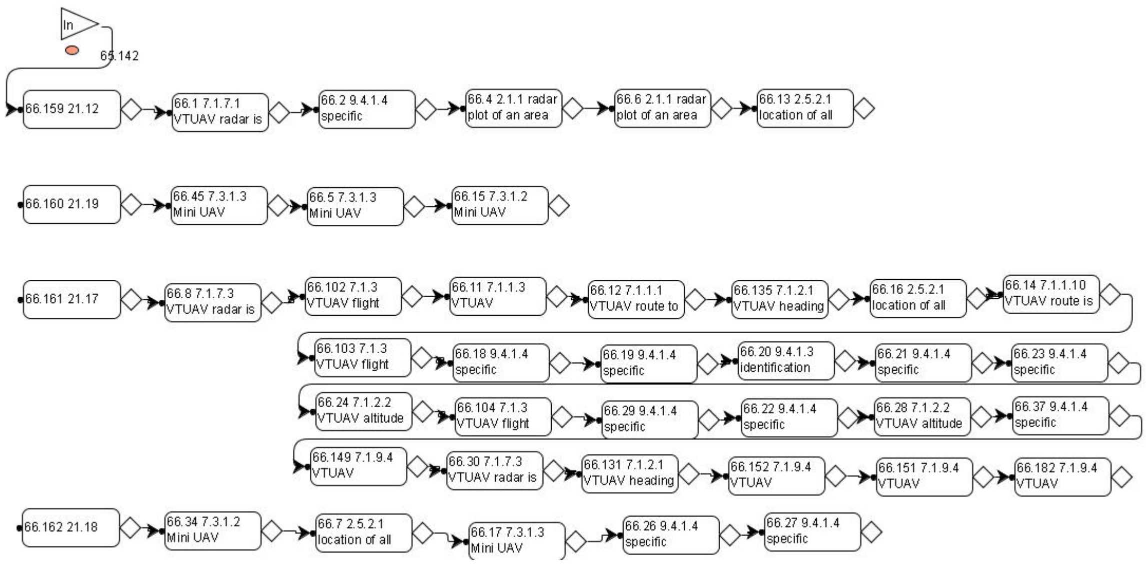

Figure 16: Sub-network that Represents Goals

This model reads in data from three CSV files:

1. "TaskIDstoGoalIDsSorted.csv" contains a mapping of IPME task IDs to goal IDs.

2. "UniqueStatementList.csv" contains the names of each task and knowledge statement that is used in the model.

3. "GoalIDStatementDutyAreaList.csv" contains the list of task and knowledge statements required by each goal ID.

Four snapshots were added to collect simulation outputs using the plain text format option in IPME version 4. The snapshots are described in detail in Section 5.2.3.

5.2.1 Crew Model

It took some thoughtful consideration to determine the best method for adding the TK statements to the crew model. Manually searching through each of the four MOS databases would have required 2,284 key word searches to locate the 571 unique TK statements using CAMA. This was considered unrealistic and an alternative solution was sought.

Instead, the MOS databases were searched using the same database query that identified the duty area name. This query showed that:

1. 354 statements did not exist in any of the CAMA databases,

2. 159 statements had a unique match in one of the CAMA databases, and

3. 58 statements matched multiple duty areas in one or more of the CAMA databases.

To resolve the 58 ambiguous statements, the statement belonging to the assumed duty area name was selected as the best match. If the duty area for the statement did not match the assumed duty area name, then this occurrence was not considered a match. A matching statement belonging to the correct duty area can occur multiple times in the databases if it is associated with multiple jobs. Since each occurrence can have a different proficiency value, the proficiency value from the first matching occurrence was always used.

After disregarding TK statements that were not available in CAMA, a total of 217 TK statements remained. These TK statements were added to the crew model. Note that this implementation was not efficient because it resulted in unused statements being added to the crew model as operator traits. Minor usability and efficiency issues resulted since it took analysts more time to locate the TK statement in the long trait lists and the saved model file was larger. However, since these unused traits were not accessed in the task network model, they had no impact on the model outputs, and, therefore did not affect the validity of the model.

By assigning the operators in this crew model every TK statement available from the MOS databases, we represented the *best possible operator*. This provided us with the *most desirable JSI values* which could be used as a benchmark for more realistic operator structures. Note due to the missing 354 TK statements in the CAMA databases, the JSI computation for the best possible operator would not generate a perfect score (i.e., 1).

5.2.2 Alternative Crew Model

Two sets of candidate occupations were compared to assess how operators from existing AF occupations would perform in the MC, PO, and VO roles. The selected candidate occupations were chosen based on the completeness of information in the MOS databases. The modeller possessed no information that suggested either of the two candidate occupations were strong candidates for the MC, PO, and VO positions.

1. Three operators were assumed to possess occupational training as air mobility navigators. That is, the operators possessed the skills specified in the TK statements for an air mobility navigator. For documentation purpose, these TK data, together with the proficiency scores, are currently stored in the MOSID-ANAV database. The resulting crew model is named “ANAV182AirNav162AirMobilInstrNav.”

2. In the other crew model, each of the three operators possessed occupational training as a maritime helicopter tactical control officer. That is, the operators each had acquired the task and knowledge statements for a maritime helicopter tactical control officer. This TK data, together with the proficiency scores, were stored in MOSID-PILOT database. The resulting crew model is named “PILOT182AirNav203MarHeliTacCO.”

These two crew models were assigned to the IPME UAV system model in place of the original “best possible operator” crew model. The impact of the different crew compositions was reflected in the JSI outputs.

5.2.3 Model Output

Since the default IPME outputs were not sufficient for this study, snapshots were created to collect customized simulation data. Snapshots are internal constructs in IPME for recording the values of selected variables at specified points during model execution. These data can be used to generate statistics and graphs. For the UAV IPME model, four snapshots were created.

- JSISnap - This snapshot recorded the name of the operator assigned to this task, the JSI value for the assigned operator, and the task name (which includes the goal ID).
- JSIValues - This snapshot recorded the name of the operator assigned to this task, the JSI value for the assigned operator, and the name of the task (which includes the goal id). This snapshot was easily imported into Microsoft Excel for further analysis.
- NoGoalFound - This snapshot recorded the goal IDs for which we have task and knowledge statements, but were not included in the IPME model.
- TasksNoRequirements - This snapshot recorded the goal IDs for tasks which do not have any required task or knowledge statements.

5.3 Results

5.3.1 Crew Results

Table 10-Table 12 list the results of the “JSIValues” snapshot. Note that the snapshots “JSISnap” and “JSIValues” contain identical data; only their format is different. JSI scores for the “best possible crew” did not equal 1.0 due to a practical constraint of this study (missing 354 TK statements in the MOS databases). A cell value of “N/A” indicates that the task was not performed, so the JSI value was not calculated.

Table 10: MC Operator JSI Values per Task

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
2.1.1	radar plot of an area of interest is current	0.36	0.21	0.31
2.5.2.1	location of all unknown unit icons on tactical plot	0.36	0.18	0.32
3.5.1	command and control of tactical situation is assessed	0.41	0.07	0.41
3.5.2	determination of the SAC (OSC) is completed	0.34	0.07	0.34
4.4.10	contact can be identified	0.00	0.00	0.00
5.1.3	relevant rules of engagement are reviewed	0.26	0.04	0.26
5.2.1	overt actions of terrorist unit personnel are observed	0.17	0.05	0.18
5.3.1	potential weapons onboard terrorist unit	0.24	0.11	0.24
5.3.8	risk to neutral units	0.13	0.13	0.13
5.5.2	selection of best units to counter terrorist threat	0.29	0.11	0.29

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
5.5.2	selection of best units to counter to terrorist threat	0.29	0.11	0.29
5.5.6	selection of the best offensive systems	0.29	0.11	0.29
5.6.3	tasking message has been transmitted	0.26	0.14	0.25
5.7.8	damage report provided to friendly unit	0.31	0.19	0.31
6.4.1	the probable position of the terrorist vessel	0.27	0.16	0.25
6.4.4	search area is appropriate for current situation	0.20	0.10	0.20
6.4.5	display area on workstation is appropriate	0.33	0.22	0.33
6.8.1	need for contingency plans is addressed	1.00	1.00	1.00
6.8.2	contingency plans are created	0.41	0.41	0.41
6.8.3	contingency plans are discussed	0.00	0.00	0.00
7.1.1.8	VTUAV activities are planned	0.00	0.00	0.00
7.1.1.11	handover of VTUAV has been prepared	0.26	0.26	0.26
7.3.1.2	Mini UAV search pattern is planned	0.38	0.31	0.38
7.3.1.10	crew is briefed on use of Mini UAVs	0.43	0.43	0.43
7.3.1.11	crew have been requested to launch Mini UAV	0.00	0.00	0.00
7.3.3.5	Mini UAV is autonomously following contact	0.00	0.00	0.00
7.3.5.10	CONT EO images are organized on desktop	1.00	0.00	0.00
7.3.8.1	previous minutes of video are reviewed	0.25	0.00	0.25
9.3.2.3	fighter aircraft are directed to attack threat	0.26	0.16	0.24
9.4.1.5	information of a general nature	0.22	0.00	0.11
10.1.2.1	MC workstation is configured	0.25	0.00	0.25
2.1.1	radar plot of an area of interest is current	0.36	0.21	0.31
2.5.2.1	location of all unknown unit icons on tactical plot	0.36	0.18	0.32
3.5.1	command and control of tactical situation is assessed	0.41	0.07	0.41

Table 11: PO Operator JSI Values per Task

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
2.1.4	tactical plot icons are current	0.32	0.18	0.28
4.1.5	latest position of all unknown contacts is plotted	0.35	0.21	0.30
4.2.5	contact is sought using UAV radar	0.17	0.09	0.17
4.4.5	crew identifying vessel using UAV EO suite	0.29	0.06	0.29
4.4.7	UAV images of boat are compared with database	0.20	0.07	0.20
4.4.8	crew classify vessel using UAV EO suite	0.60	0.00	0.60
5.6.4	tasking message has been acknowledged	0.26	0.16	0.24
7.1.4.1	VTUAV EO sensor settings are optimized	0.21	0.00	0.21
6.9.1	VTUAV piloting aspects are studied	N/A	N/A	0.38
7.1.1.1	VTUAV route to the next operating area is planned	N/A	N/A	0.41
7.1.4.2	VTUAV EO sensor is used for a test observation	1.00	0.00	1.00
7.1.1.10	VTUAV route is plotted	N/A	N/A	0.50
7.1.1.2.1	selection of an appropriate search pattern	N/A	N/A	0.37
7.1.5.7	VTUAV EO image file is stowed	0.33	0.00	0.33
7.1.9.1	VTUAV data uplink is maintained	0.20	0.00	0.20
7.1.1.2.7	location of contact symbol is determined on tacplot	N/A	N/A	0.43
7.1.9.3	initial system settings on VTUAV are reviewed	0.10	0.10	0.10
7.1.1.6.1	location of potential VTUAV refueling platforms	N/A	N/A	0.45
7.3.4.1	Mini UAV EO sensor settings are optimized	0.14	0.00	0.14
7.1.1.6.2	estimated CPF location at time off task	N/A	N/A	0.38
7.3.5.2	Mini UAV EO sensor is used to study a contact	0.25	0.00	0.25
7.1.1.6.4	rough VTUAV time on task is calculated	N/A	N/A	0.00
7.3.5.4	Mini UAV EO zoomed in on a portion of boat	0.00	0.00	0.00
7.1.1.6.6	any problems associated with refueling	N/A	N/A	0.00
7.3.5.6	Mini UAV EO sensor is used to track a contact	0.14	0.05	0.14
7.1.2.1	VTUAV heading has changed to a new heading	N/A	N/A	0.36
7.3.5.7	Mini UAV EO is used to record high definition images	0.00	0.00	0.00
7.1.2.1	CONT VTUAV heading has changed to a new heading	N/A	N/A	0.36
7.3.5.8	Mini UAV FOV trapezoid is over contact	0.00	0.00	0.00
7.1.2.2	VTUAV altitude has changed to a new altitude	N/A	N/A	0.34
9.4.1.3	identification and activities of contact	0.24	0.14	0.19
7.1.2.4	VTUAV autopilot set to autonomous mode	N/A	N/A	0.17

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
7.1.3	VTUAV flight path is monitored	N/A	N/A	0.36
10.1.2.3	PO workstation is configured	0.25	0.25	0.25
7.1.5.6	VTUAV EO images are monitored	N/A	N/A	0.33
7.1.5.7	VTUAV EO image file is stowed	N/A	N/A	0.33
7.1.9.2	initial system checks on VTUAV are conducted	N/A	N/A	0.25
7.1.9.4	VTUAV systems are monitored	N/A	N/A	0.00
7.3.1.8	Mini UAV route is plotted	N/A	N/A	0.33
7.3.2.1	Mini UAV heading has changed to a new heading	N/A	N/A	0.29
7.3.2.2	Mini UAV altitude has changed to a new altitude	N/A	N/A	0.31
7.3.3.1	Mini UAV symbol has appeared on the surface plot	N/A	N/A	1.00
7.3.3.2	Mini UAV is in descent following deployment	N/A	N/A	0.33
7.3.3.3	CONT Mini UAV is following the planned flight path	N/A	N/A	0.50
7.3.7.2	initial system checks on Mini UAV are conducted	N/A	N/A	0.44
7.3.7.3	Mini UAV systems are monitored	N/A	N/A	0.33
7.3.7.4	Mini UAV systems are managed	N/A	N/A	0.33
9.4.1.4	specific information regarding a UAV	N/A	N/A	0.00

Table 12: VO Operator JSI Values per Task

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
6.9.1	VTUAV piloting aspects are studied	0.41	0.36	0.38
7.1.9.2	initial system checks on VTUAV are conducted	0.30	0.20	0.25
7.1.1.1	VTUAV route to the next operating area is planned	0.44	0.41	0.41
7.1.3	CONT VTUAV flight path is monitored	0.36	0.32	0.36
7.1.1.10	VTUAV route is plotted	0.50	0.50	0.50

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
7.1.1.2.1	selection of an appropriate search pattern	0.37	0.29	0.37
7.1.1.6.4	rough VTUAV time on task is calculated	0.00	0.00	0.00
7.1.1.2.7	location of contact symbol is determined on tacplot	0.43	0.14	0.43
7.1.1.6.1	location of potential VTUAV refueling platforms	0.45	0.29	0.45
7.1.1.6.2	estimated CPF location at time off task	0.38	0.13	0.38
7.1.2.1	CONT VTUAV heading has changed to a new heading	0.40	0.36	0.36
7.1.1.6.6	any problems associated with refueling	0.00	0.00	0.00
9.4.1.4	specific information regarding a UAV	0.00	0.00	0.00
7.1.2.2	VTUAV altitude has changed to a new altitude	0.41	0.34	0.34
7.1.2.4	VTUAV autopilot set to autonomous mode	0.17	0.17	0.17
7.1.3	VTUAV flight path is monitored	0.36	0.32	N/A
7.1.9.4	VTUAV systems are monitored	0.00	0.00	0.00
7.1.5.6	VTUAV EO images are monitored	0.33	0.00	0.33
7.1.9.2	initial system checks on VTUAV are conducted	0.30	0.20	0.25
7.3.3.1	Mini UAV symbol has appeared on the surface plot	1.00	0.00	1.00
7.3.3.2	Mini UAV is in descent following deployment	0.33	0.00	0.33
7.3.7.2	initial system checks on Mini UAV are conducted	0.56	N/A	0.44
7.3.1.8	Mini UAV route is plotted	0.33	0.33	0.33
7.3.2.1	Mini UAV heading has changed to a new heading	0.43	0.29	0.29
7.3.2.2	Mini UAV altitude has changed to a new altitude	0.38	0.31	0.31
7.3.7.3	Mini UAV systems are monitored	0.33	0.33	0.33
7.3.7.4	Mini UAV systems are managed	0.33	0.33	0.33

Task ID	Task Name	Best Possible Crew JSI	Air Mobility Instructor Navigator Crew JSI	Maritime Helicopter Tactical Control Officer Crew JSI
7.3.3.3	CONT Mini UAV is following the planned flight path	0.50	0.25	0.50

Table 13 lists the minimum, maximum, and average JSI values for the three operators. The tasks where the JSI was equal to 1.0 are listed, which indicates a perfect match of the operator's TK statements to that task's TK requirements. Upon further analysis, it would have been beneficial to record any tasks with zero JSI scores, since such scores indicate that the assigned operator does not possess any relevant knowledge or skills, indicating a complete qualification gap.

Table 13: Summary of Operator JSI Values

Crew and Operator		Average JSI	Minimum JSI	Maximum JSI	Tasks with JSI=1.0
Best Possible Crew	MC	0.29	0	1	6.8.1 need for contingency plans is addressed 7.3.5.10 CONT EO images are organized on desktop
	VO	0.35	0	1	7.3.3.1 Mini UAV symbol has appeared on the surface plot
	PO	0.25	0	1	7.1.4.2 VTUAV EO sensor is used for a test observation
Air Mobility Instructor Navigator Crew	MC	0.15	0	1	6.8.1 need for contingency plans is addressed
	VO	0.33	0	1	7.3.3.1 Mini UAV symbol has appeared on the surface plot
	PO	0.23	0	0.4140256	None
Maritime Helicopter Tactical Control Officer Crew	MC	0.25	0	1	6.8.1 need for contingency plans is addressed
	VO	0.33	0	1	7.3.3.1 Mini UAV symbol has appeared on the surface plot
	PO	0.24	0	1	7.1.4.2 VTUAV EO sensor is used for a test observation

5.3.2 Discussion

Ideally, we would continue to explore substituting additional occupations into the crew model to achieve the highest JSI possible. Due to time constraints of the project, only two such substitutions were performed. The average JSI results of the crews are presented in Table 13. A comparison of the JSI results for the Air Mobility Navigator and the Maritime Helicopter Tactical Control Officer is presented in Table 14.

Table 14: JSI Scores as a Percentage of Best Possible Crew JSI

Operator	Air Mobility Navigator	Maritime Helicopter Tactical Control Officer
MC	50.5%	86.5%
VO	18.7%	94.2%
PO	91.7%	96.3%

The following basic conclusions were drawn from the simulation results.

1. None of the selected occupations, including the hypothetical 'best possible crew,' was able to satisfy all of the knowledge and skills requirements imposed by three UAV operator positions.

2. Overall, the JSI scores were fairly low. However, if you compare the JSI scores to the best possible crew JSI scores, the best match is obtained by placing the Maritime Helicopter Tactical Control Officer in the PO role. Placing the Air Mobility Navigator in the VO role resulted in the worst match.

3. The Maritime Helicopter Tactical Control Officer was "more qualified" to serve in all three roles than the Air Mobility Instructor Navigator, as shown by higher JSI scores.

The objective of this modeling exercise was to identify CF occupations that satisfied the knowledge and skills requirements imposed by each of three UAV operator roles. An ideal occupation (if it exists) would generate a JSI score of one for all designated tasks. Any imperfect JSI result reflects a potential opportunity for performance breakdown and is an indication that further training is needed. Since currently there are no Air Force occupations that correspond directly to each of these UAV operator jobs, perfect JSI scores could not be generated. The 'best possible crew' in the study should be interpreted as the 'best possible' solution available from the existing MOS database. Without a complete occupational dataset from the Canadian Air Force, the conclusion was not informative. However, it did demonstrate the usefulness of incorporating such a hypothetical crew model for assessing the amount deviation of an actual occupation (e.g., a maritime helicopter tactical control officer) in fulfilling job requirements from that of a hypothetical "best possible' solution.

The JSI scores presented in Section 5.3.1 provide some insight about the goodness of fit between selected AF occupations and the designated UAV operator roles. An occupation with a higher JSI score is interpreted as a better fit to these roles. However, it is important to note that the

quantitative JSI scores can not be used directly for interpreting operator performance. For example, for the VO role, the Maritime Helicopter Tactical Control Officer generated a JSI 5.5 times larger than that of an Air Mobility Navigator. However, this does not imply that the Maritime Helicopter Tactical Control Officer would perform 5.5 times better. Implications of this nature need to be studied in the conventional framework of IPME modeling, using performance shaping functions that define the numerical relations between operator characteristics and performance indicators (e.g., task execution times or system failure rates). Such methods could also be used to identify minimum acceptable JSI scores for each task. With the support of additional data, the relationship between occupational definitions and task performance could be studied in a more robust IPME model.

6 ISMAT Model

6.1 ISMAT Modeling Process

The Integrated Simulation Manpower Analysis Tool (ISMAT) was specifically designed and developed to support U.S. Navy ship manning concepts and was not intended to be a general purpose human performance modeling tool. As such, ISMAT includes a large library of U.S. Navy crew, organization, and equipment data. There is a large maintenance manpower analysis portion that was not utilized for this effort. The scope of the functional analyses that can be modeled with ISMAT includes operations, facilities maintenance, planned preventive maintenance, and unplanned corrective maintenance. Only the operations portion was used in this study.

ISMAT integrates skill and ability requirements with the dynamic human performance simulation framework. ISMAT allows the analyst to examine the skills required to perform specific tasks and can also describe operators in terms of what skills they possess at what level. ISMAT contains a library that provides information on specialized skills and proficiency levels that are available within the US Navy's enlisted personnel inventory, classified by rate and rating.

In ISMAT, the user describes each task in terms of the human abilities required to perform it. Using ISMAT, an analyst first systematically proceeds through the set of 50 skills and abilities and decides which ones are required for performing a particular task. The next step is to determine the demand level for the task. Each skill is rated on a scale from 0 to 70. The user can either manually enter a score or use a sliding scale to pinpoint the proper location.

Once the user has determined what KSAs are required for a task, ISMAT queries the crew profiles and presents the user with a list of all existing operators that meet or exceed the task KSA requirements. The users can then select one or more operators from the list, or define new operators manually. The process of defining a new operator involves entering a name, defining the rank, rating, and the associated skills and abilities.

While the generic ISMAT modeling approach is available in its users' manual [8], the following list representing a simplified view of the modeling process is provided for the reader's convenience.

1. Crew parameter definition

This is where the characteristics of crew are defined. This process consists of two parts: firstly the selection of crew members and secondly the specification of such crew parameters as skills, availability (work hours per week) and cost.

2. Scenario and function parameters definition

ISMAT functions are analogous to IPME networks. The definition of functions involves the specification of task parameters such as skills and abilities requirements, whereas the definition of scenarios is accomplished by adding specific functions and tasks to operators. The top level

networks are defined using a GANTT-Chart style editor. The top-level functions/networks can optionally be decomposed to the task level.

3. Assign crew to functions/tasks

Each non-automated function or task must be assigned to one or more operators. ISMAT searches the crew skill profiles and shows the user which crew member(s) meet or exceed the skill levels required by the function/task. If the crew member(s) do not meet or exceed the skills requirements they are highlighted in red. The user specifies the required crew size for each function / task as well as which operators might perform the function/task. This allows user to optionally develop operator "pools" that allow dynamic allocation of jobs to tasks to occur as the simulation is running. Whenever a task is scheduled to begin, ISMAT determines the “best” operator(s) according to the user specified goal (e.g., minimize cost, minimize crew size, minimize workload) and operator availability.

4. Model executition

Once the analysis has been defined, ISMAT automatically generates a discrete-event simulation model from the user’s inputs and executes the tasks as they would be performed in a real scenario, taking into consideration the variability in task performance time and accuracy. Unlike a static flow diagram of activities, the models created with ISMAT are able to simulate the interplay of activities and influences between crewmembers, automation devices, and conditions outside of the environment of the system being modeled.

5. Result analysis

ISMAT automatically generates several reports that summarize operator skill usage, function or task performance, and the level of operator utilisation. Such results are applied for diagnosing system designs. Users can also define their own data collection snapshots.

6.2 UAV ISMAT Modeling Approach

The version of ISMAT used in this study was version 1.1, distributed on 27 July 2006. This section provides a detailed account of the ISMAT model development process, particularly the challenges that were encountered and their corresponding solutions.

1. UAV model conversion

In order to save time and reduce the possibility of errors, we used several different ways of automatically importing the model data directly from IPME.

The initial import attempt used data from IPME’s Spreadsheet Editor. The relevant model data, e.g., the name and meantime columns in the Spreadsheet Editor, were first copied and pasted to a Microsoft Excel spreadsheet. Additional manual editing was required to produce a tab-delimited text file compatible with ISMAT. However, because this method was time-consuming and difficult to reproduce (e.g., in case of IPME model changes), a temporary solution was used by adding a new menu option “Save Network as ISMAT File” in a development version of IPME.

This option simplified the process of importing task information, such as names and mean times, but other type of data still had to be manually entered.

Alternatively, we explored the use of a Microsoft Excel data import format supported by ISMAT. This option allowed the automatic convertion of intra-task pathways into an ISMAT format. Since this feature was revealed to be desirable for general modeling purpose, a new export function was added to the IPME in which a new menu option "Save as CSV" was added to the task network and crew models in the commercially distributed version of IPME. Note the CSV file generated by this menu command does not record the complete model data, only those that are used for the ISMAT model is captured in the CSV file. Once the CSV files for the task network and crew models were generated, they were manually converted to the Microsoft Excel format. The list below shows the relevant task information supported by this import process.

- Task Name
- Task ID
- Mean Time
- Time Distribution
- Standard Deviation
- Beginning Effect
- Ending Effect
- Following Task(s)

Due to syntax differences between IPME and ISMAT, minor changes were made to the model after it was imported into ISMAT. In particular, any continuous task in IPME was manually converted into a series of three tasks in ISMAT (see Figure 17).

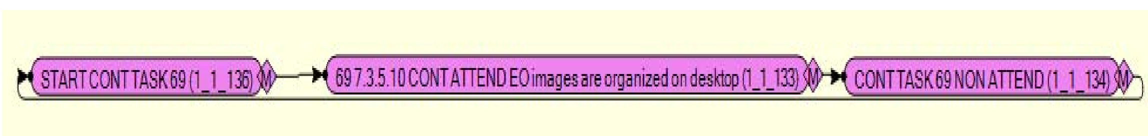

Figure 17: Continuous Task Group in ISMAT

In IPME, a continuous task can be defined which has two time parameters: an attending time and a non-attending time [1]. Such construct is not available in ISMAT, as a result, tasks in ISMAT are always discrete. In order to translate an IPME continuous task into ISMAT, a series of three discrete tasks was used in ISMAT (see Figure 17). Within this task group, the first task is a starter and it contains logics that compute the active time (the mean time for the attending task), the total duty cycle time, and the mean time for the non attending task; the following two tasks represent the attending and non-attending portion of the continuous task respectively. In this study, the starter task was not assigned to any crew member, while the attending and non attending tasks were assigned to the associated operator.

For some tasks in the IPME model, their standard deviation for task completition time used internal variables such as Entity.MeanTime. Such expressions could not be used in an ISMAT

model. Consequently, adjustments were made and those expressions were changed to their numeric equivalent in the ISMAT model.

In addition, the IPME model contained three nextTask() functions that started tasks in each of the sub-networks via start() function calls. These nextTask() functions were removed in the ISMAT model and replaced with paths connecting the tasks. This modification did not change the order in which tasks executed.

2. Crew definition

Crew selection in the ISMAT model presented a series of challenges. ISMAT contains a library of jobs selected from the US naval occupations. Because of the lack of direct mapping between MOS TK statements (used in IPME) and the Fleishman human skill taxonomy (used in ISMAT), the IPME crew could not be directly imported into ISMAT. In consultation with the project's scientific authority, it was decided to select similar (i.e., not identical) occupations for defining crew members in the ISMAT model.

A first attempt was made which included a two-step process for identifying naval occupations in ISMAT that were similar to the Canadian Air Force occupations tested in the IPME model. First, we identified US Air Force occupations that corresponded to the Canadian ones; second, we mapped those US AF occupations to the US Navy occupations. The basis for the mapping was knowledge and skills requirements.

Specifically, operators' job titles that were tested in IPME (e.g., an air mobility instructor navigator or a maritime helicopter tactical control officer), were used as keywords for searching the Occupational Information Network (O*NET) which is available through http://online.onetcenter.org. The O*NET database includes occupational information for the entire US military. The following steps were taken to identify candidate occupations to use in the ISMAT model

1. Search for these keyword strings in the O*NET database.
2. Scan the list of search results for related US AF occupations.
3. Find the corresponding O*NET occupations.
4. Find the corresponding US Navy occupations.

Table 15 and Table 16 display results obtained for mapping to the air mobility instructor navigator and the maritime helicopter tactical control officer respectively.

Table 15: Candidate Occupations related to an Air Mobility Instructor Navigator

US AF	US Navy	O*NET
81T0W Instructor, General (Air Force - Commissioned Officer only)	8235 Instructor, General	25-3099.99 Teachers and Instructors
12M1Y Mobility Navigator, General (Air Force - Commissioned Officer only)	No match found.	53-2011.00 Airline Pilots, Copilots, and Flight Engineers
12M1Z Mobility Navigator, Other (Air Force - Commissioned Officer only)	No match found.	53-2011.00 Airline Pilots, Copilots, and Flight Engineers

Table 16: Candidate Occupations related to a Maritime Helicopter Tactical Control Officer

US AF	US Navy	O*NET
11H1Y Helicopter Pilot, General (Air Force - Commissioned Officer only)	No match found.	53-2012.00 Commercial Pilots
11H1Z Helicopter Pilot, Other (Air Force - Commissioned Officer only)	No match found.	53-2012.00 Commercial Pilots
13B1 Command and Control Operations (Air Force - Commissioned Officer only)	Closest match: 0342 Global Command and Control System Common Operational Picture/Maritime (GCCS COP/M) Operator	55-1015.00 Command and Control Center Officers
7380 Tactical System Officer/Mission Specialist (Marine Corps - Warrant Officer only)	No match found.	53-2011.00 Airline Pilots, Copilots, and Flight Engineers
	0322 LAMPS MK III Air Tactical Control Operator (Navy - Enlisted)	55-3015.00 Command and Control Center Specialists

Additionally, queries were conduced in the Military Occupational Classification (MOC) to Standard Occupational Classification (SOC) Crosswalk database. This database supports queries using occupation codes from different classification systems, e.g., dictionary of occupational titles, military occupational classification, standard occupational classification, registered apprenticeship information system, and classification of instructional programs. The outputs of these queries were three US naval occupations:

- 8235 Instructor, General
- 0342 Global Command and Control System Common Operational Picture/Maritime (GCCS COP/M) Operator

- 0322 LAMPS MK III Air Tactical Control Operator (Navy - Enlisted)

However, an internal search in ISMAT manning documents revealed that none of these occupations were available in existing ISMAT databases. The reason none of the occupations existed is because the codes obtained from O*NET are not the same type of codes used in ISMAT. The analyst should have been looking for the Primary Rating field in O*NET rather than the MOC field in order to find matching descriptors. In ISMAT version 1.1[1] operators are defined in terms of rating (BM – boatswain mate, OS- operations specialist, etc.) and rank (E1-recruit, E2-apprentice, E3-seaman, E4-petty officer 3rd class, etc.). The MOC codes that were obtained via the O*NET and crosswalk search are Navy Enlisted Codes (NECs) or Navy Officer Billet Classification (NOBC) codes. In the U.S. Navy each sailor has one rank and rating but may have multiple NECs depending on what schools and training they have attended. Therefore, this approach failed to generate matching occupations in the ISMAT database that were representative of the occupations tested separately in the IPME model.

An alternative attempt was made by examining the occupational database for a CVN 68 Nimitz-class aircraft carrier. This process produced the following list of occupations that were eventully applied in the ISMAT model, as shown in Figure 18.

Selected Crew					
Billet	Name	Rating	Grade	Department	Division
00001	ELECTRONICS TECHNICIAN	ET	E4	OPERATIONS	OE
00002	RADIOMAN	RM	E5	OPERATIONS	OC
00003	OPERATIONS SPECIALIST	OS	E7	OPERATIONS	OI
00004	ALL-NAVY	ANYBODY	E9	EXECUTIVE	EXECUTIVE
00005	ALL-NAVY	ANYBODY	E1_3	AIR	V
00006	SIGNALMAN	SM	E1_3	NAVIGATION	N
00007	SIGNALMAN	SM	E7	NAVIGATION	N
00008	BOATSWAIN'S MATE	BM	E4	DECK	2ND
00009	ALL-NAVY	ANYBODY	E1_3	ENGINEERING	A

Figure 18: Screenshot of Initial Selected Crew for ISMAT UAV Model

Note that different from the IPME model where operators (with occupational specification) were statically assigned to each task, ISMAT was able to automatically choose an operator for each task based on the scenario goal. In order to take advantage of this capability in ISMAT, a pool of virtual operators with a variety of occupational backgrounds (see Figure 16) was created and used in the test. The entire operator pool was assigned to each task, so that the build-in ISMAT algorithm could work effectively to determine the approproriate operator assignment dynamically.

[1] Note: ISMAT version 2.0 includes NEC/NOBC profiles as well as O*NET profiles for describing crew members.

6.3 The ISMAT Model

The completed ISMAT model consisted of three functions (networks) and 397 tasks. The critical tasks, as identified by [2] are listed in Table 17 along with their corresponding task IDs in the ISMAT model. A complete list can be found in [1].

Table 17: Critical Task Sequence

Goal ID	Description	ISMAT Task IDs
4.4.5	crew identifying vessel using UAV EO suite	65_35 65_39 65_47 65_50 66_65 66_67
4.4.6	ISAR imagery is downloaded and analysed	67_6
4.4.7	UAV images of boat are compared with database	66_54
4.4.8	crew classify vessel using UAV EO suite	66_55 66_59
4.4.9	legality of fishing boat activities	66_68 66_75
4.4.10	contact can be identified	66_78

For each critical task, skill requirements were specified based on the Fleishman human skill taxonomy. Skill requirements were not defined for any of the non-critical tasks. Due to the lack of supporting data, the skill assignments were made arbitrarily in this study. A sample assignment is provided in Table 18. This was considered acceptable since the intent was to examine the modeling process.

Table 18: Critical Tasks Required Skill Set

Skill Name	Score
Deductive Reasoning	49
General Hearing	41
Inductive Reasoning	35
Oral Comprehension	35
Oral Expression	37

A single scenario, named *UAV*, was created for the model. This scenario had three functions: coded 65, 66, and 67 respectively. They were identical to three sub-networks in the IPME model. Each function was decomposed into mostly the same tasks (with an exception on continous tasks, as discussed before) as the IPME model. Additionally, the IPME model had a few dummy tasks for data collection; they were removed in the ISMAT model. Figure 19 shows a scenario schedule, with each function set to one hour in duration, and Figure 20 illustrates a portion of the decomposed sub-task network for Function 65.

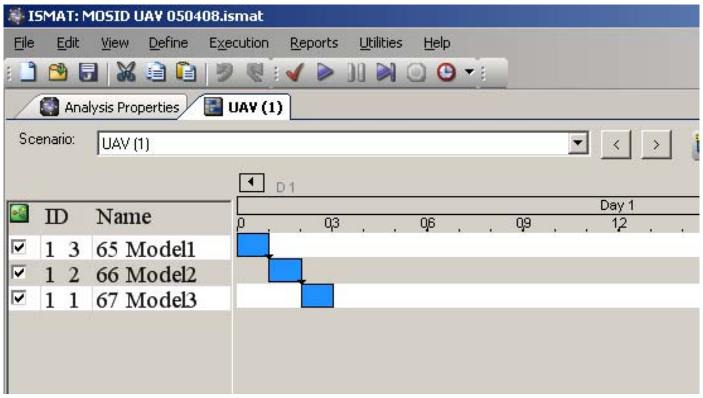

Figure 19: UAV Scenario Schedule

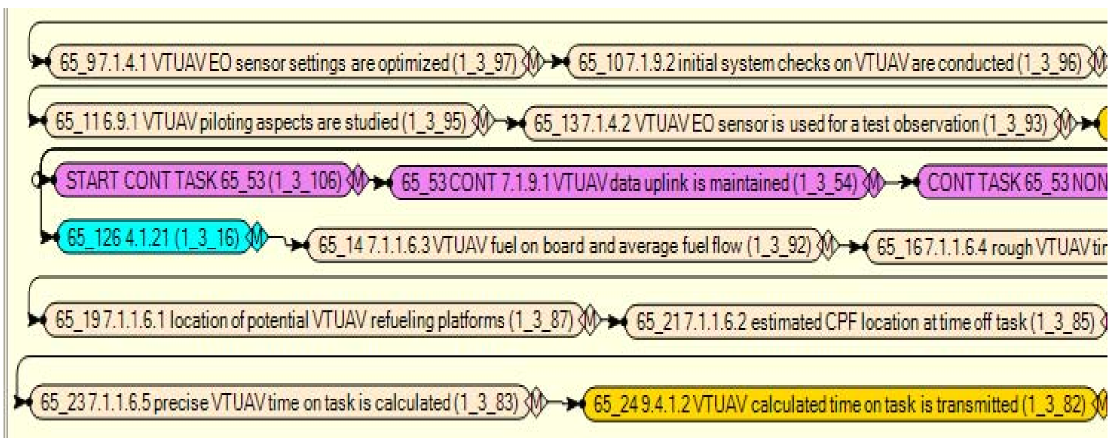

Figure 20: Partial Task Decomposition of Function 65

Human tasks in the ISMAT model were populated with timing information. In this study, each ISMAT task's timing data (e.g., task completion mean time, and standard deviation) were identical to their counterpart in the IPME model. Task skill requirements were specified using the Fleishman skill taxonomy for critical tasks only. For other task parameters, the ISMAT default values were used. **Error! Reference source not found.** and **Error! Reference source not found.** show how a typical ISMAT task is populated with both timing information and skill requirements.

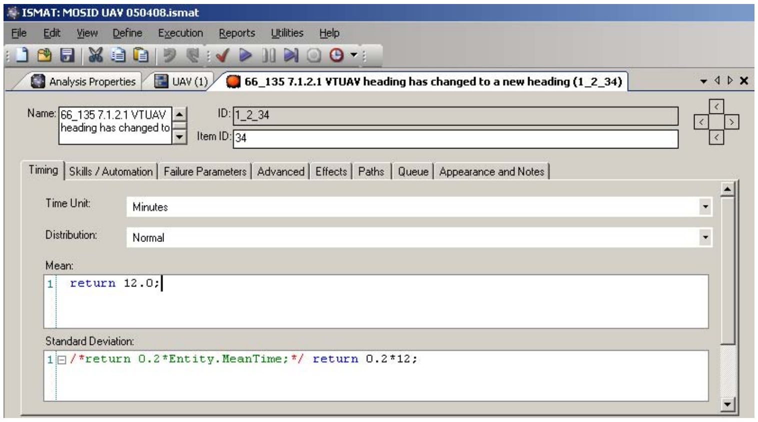

Figure 21: Task timing information in ISMAT

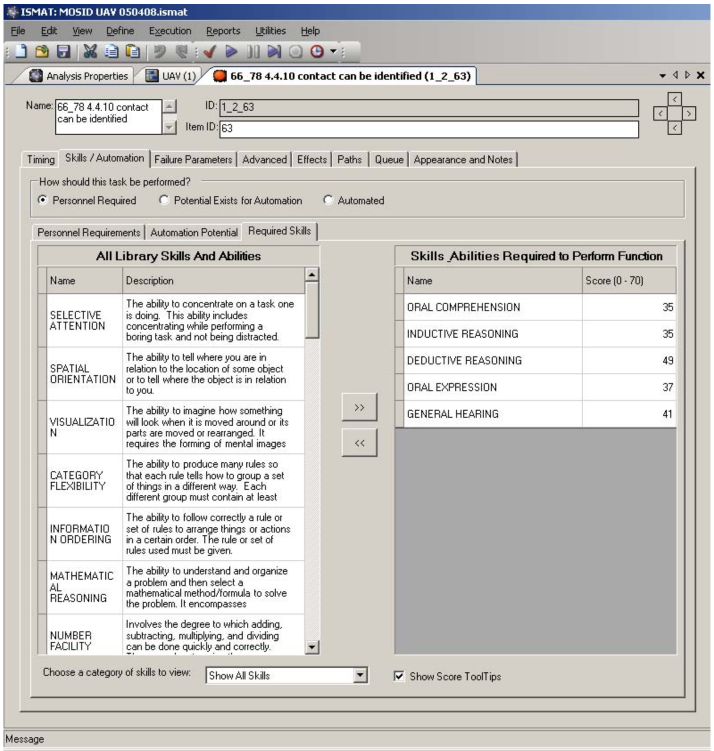

Figure 22: Task skills requirement in ISMAT

6.3.1 Model Output

ISMAT automatically produces twenty three different reports as shown in Figure 23.

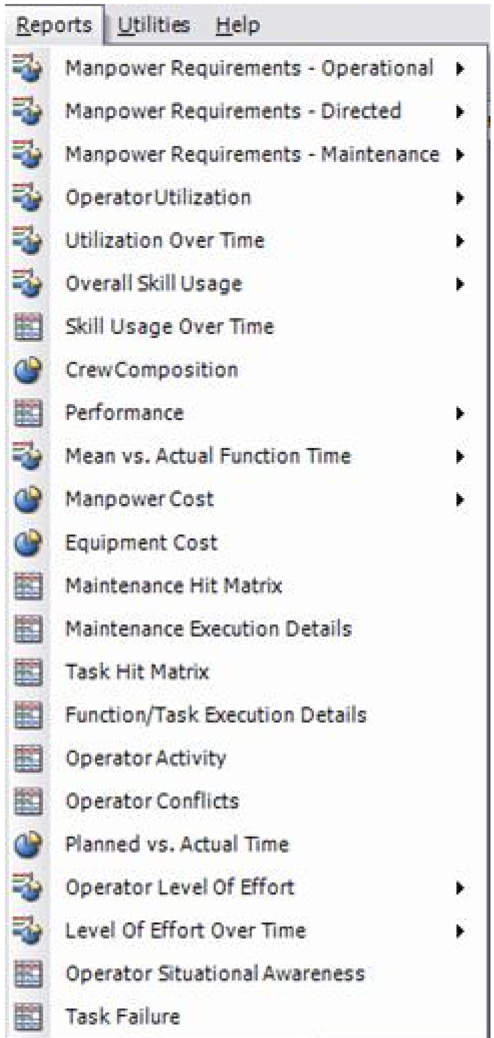

Figure 23: ISMAT Reports

Output parameters include manhour requirements, planned versus actual mission performance, a listing of functions/tasks that were delayed due to manpower constraints, relative cost, equipment failure, maintenance manhour requirements, and skill and ability usage.

While an ISMAT model produces a number of different reports, only the Overall Skill Usage report was examined for this project. This is the report that most closely matches the JSI Values reported in the IPME model results section.

- Overall Skill Usage – This report can be used to describe the skills that are needed to perform a particular job during the conduct of the simulated scenario. It shows the cumulative skill usage by job for all 8 major skill categories (Auditory, Communication, Conceptual, Fine Motor, Gross Motor, Reasoning, Speed Loaded, and Visual). The report also shows the percentage of total skill usage that can be attributed to each skill category. This report can be viewed either in tabular or graphical format.

A sample output from this UAV model (see Figure 24) showed that the operators used Auditory, Communication, and Reasoning skills when performing the mission critical tasks.

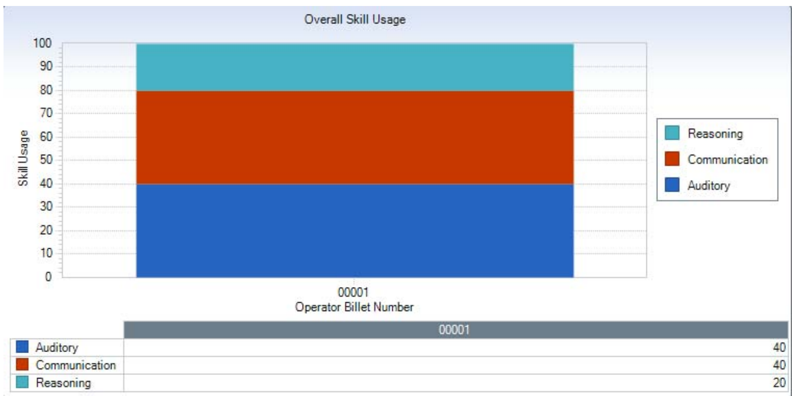

Figure 24: Overall Skill Usage Report

In this particular case, this result was expected because only 5 skills out of 50 possible were assigned to the critical tasks as shown in Table 19.

Table 19: Skills and Categories Assigned to Critical Tasks

Skill Name	Category	Score
Deductive Reasoning	Reasoning	49
General Hearing	Auditory	41
Inductive Reasoning	Reasoning	35
Oral Comprehension	Communication	35
Oral Expression	Communication	37

Overall, it is difficult to identify a single occupation as the “best” to perform the tasks in ISMAT without consultation with a SME to obtain missing data such as operator level of effort, task priority, and skill requirements. The model outputs indicate that it is more appropriate to select required skills for all operator tasks, rather than a small subset of critical tasks. Perhaps with additional task data, it would be possible to select a specific occupation or set of occupations as appropriate for performing the tasks.

7 Discussion

This section discusses the models created in IPME and ISMAT, reviews lessons learned from the project, and provides recommendations for future work.

The same UAV scenario was modeled in IPME and ISMAT, despite the differences between the two tools (see Table 20). It was challenging to export the model from IPME and import it into ISMAT because the tools use different file formats. Additional export functionality was added to IPME to save the IPME UAV task network model in an ISMAT-compatible format. Because the ISMAT crew model could not be easily configured with MOSID task and knowledge statements, the IPME UAV crew model was not imported into ISMAT. Ideally, if ISMAT supported a more configurable crew model, functionality could be added to IPME to export the crew model in an ISMAT-compatible format.

Table 20: IPME and ISMAT Comparison

IPME and ISMAT Similarities	IPME and ISMAT Differences
Task network structure	User-defined operator characteristics available only in IPME; ISMAT uses Fleishman taxonomy
Simulation engine	Generate different outputs (IPME produced JSI values; ISMAT produced crew skill usage information)
Crew work representation	ISMAT uses level of effort; IPME uses workload

The method of incorporating task, skill, and knowledge (TSK) information into the models differed greatly. Three CSV files containing task ID, goal ID, goal descriptions, and duty areas were loaded into the IPME UAV model to populate simulation variables that were then used to calculate the JSI value for operator-task pairs. For the ISMAT model, crew members with titles related to UAV missions were selected. Fleishman skills were selected for a set of critical tasks based on the analyst's "best guess." A mapping from MOSID TSK statements to Fleishman skills does not exist. A candidate for future work could include developing this mapping, and updating the MOSID TSK statements to reflect this mapping.

The flexibility of IPME is useful, but the effort required to use the CSV files was substantial and required the help of a software developer. To simplify this step, a single, consolidated, fully populated MOS database would have been very helpful. With this database, IPME could provide a simple interface for producing a list of TSK statements.

The task expression logic in IPME calculated the JSI for operator-task pairs, and a snapshot was collected to record those JSI values. While ISMAT allows user-configured snapshots, it was not possible to calculate the JSI with the information in the ISMAT model. This forced the use of the built-in ISMAT reports to examine skill usage.

Simplifying the IPME model would have made importing the model into ISMAT easier. In the future, perhaps it would be better to use only one part of the scenario (one of the task networks from the CMC model), and avoid using continuous tasks as they have different representations and possibly different underlying execution mechanisms in IPME and ISMAT.

In conclusion, the TSK statements were useful in calculating the JSI because the JSI does provide some insightful qualitative information. The addition of the MOSID information did make a positive contribution to the UAV model in IPME. However, an argument could be made that if the Fleishman skills for CF AF occupations and the UAV scenario tasks were available, the ISMAT functionality could be just as beneficial.

Clearly, the incomplete MOS database created many difficulties in this project. The MOS data and the database structure were not consistent. Certain occupational traits were not fully specified, which limited the validity of this study. However, the model development procedure, especially the use of occupational knowledge and skills attributes in a human performance model, demonstrated a plausible solution for addressing personnel and manning issues through simulation. Although a direct contrast of simulation predictions between IPME and ISMAT was not possible, this study illustrated two different modeling approaches for addressing manning requirements. This modeling exercise focused on these differences and identified a number of areas in the current IPME implementation that demand future improvements. The list below summarizes changes that are required to address these capability gaps.

- It is important to provide a consistent data schema for storing MOS data. This is especially true for critical data relationships.
- A single database or point of entry (e.g., a graphical front-end) will reduce the effort in MOS data searching and editing.
- It is computationally easier to incorporate quantitative MOS data, rather than qualitative data, into a human performance model. Qualitative data were not directly used in the models developed for this study.
- The integrity of MOS data needs to be further validated. For example, such critical data as the occupational skill statements were not complete in the existing database. Further, the enumerated data types were not consistent within a data set.
- It requires significant effort to convert a model between applications. As we observed in this study, a great deal of time was spent reformatting the IPME task data for the ISMAT model. The adoption of a common schema for data output will reduce, but not eliminate, such effort.
- There exists a large inventory of tasks, skills and knowledge (TSK) statements for CF occupations. To choose and map these statements to a specific human task is tedious and requires the analyst to have a good understanding of the CF occupational specifications. Such TSK assignments were primarily completed on a manual level in this study. It is useful to automatize the process and reduce the effort required in the modeling process. One possible solution is to map the TSK statements to a generic human skill taxonomy for translating task requirements into occupational TSK statements.

This project represents our effort to incorporate military occupational data into human performance models. Occupational attibutes can be meaningfully linked to operator performance predictors. However, this project has not addressed many of the usability issues in the current implementation. The following list indicates future IPME development opportunities. It is weighted according to priority (highest priority first):

(1) Incorporate a generic human skill taxonomy for translating human task requirements into occupational TSK statements (e.g., MOS data);

(2) Create a TSK data collection wizard to assist in the specification of TSK statements in both task network models and crew models. The analyst will be able to choose which TSK statements apply to tasks, and allow IPME to automatically determine which operators meet those TSK requirements;

(3) Generate a set of master operators with generic levels of TSK statements that can be used in models as benchmark configurations;

(4) Since the manning requirement is often linked to specific equipment operation, it is useful to create an equipment model in IPME to address such design questions as maintenance requirements. Conventional performance measures (e.g., cognitive workload) can also be introduced when representing operators' interaction with the equipment;

(5) A Gantt chart view will enhance the visualisation of both task execution and personnel assignment.

Traditionally, modeling and simulation (M&S) have been applied to system interface design and evaluation. Although this is important for determining the effectiveness of a system, a major component of system expense is attributed to the manning cost. The addition of occupational traits in human performance models is a first step to addressing the manning requirement in a simulation environment. It creates a bridge to link M&S to the human resources (HR) cycle of activities. It is now possible to create an IPME model that describes both the task requirements (e.g., flying a UAV) and the knowledge and skills attributes that should be possessed by the operators. Such a model is able to address a range of Human Resource (HR) requirements, such as the identification of training requirements and their prioritisation. These outputs can be fed into existing HR activities for identifying a potential pool of candidate operators, formulating recruiting plans, and developing training programs. The capability developed in this project represents an expansion of modeling support for wider HSI domains. This project has further advanced our capability of using M&S for covering a larger portion of the life cycle of system development.

References

[1] Alion Science and Technology. (2008, February). IPME User Guide (Version 4.3).

[2] Farrell, P. S. E., Hubbard, P., & Culligan, I. (2006). *CFEC Project Report on the Alternative Crew Selection Method* (DRDC Ottawa TM 2006-154).

[3] Fleishman, E. A., & Reilly, M. E. (1995). *Handbook of Human Abilities: Definitions, Measurements, and Job Task Requirements*. Potomac, MD: Management Research Institute, Inc.

[4] Kobierski, B. (2004). Hierarchical Goal Analysis and Performance Modelling for the Control of Multiple UAVs/UCAVs from an Airborne Platform (DRDC Toronto CR 2004-063).

[5] MOSART. (2006). AEC/ANAV Job Description Database [Computer software].

[6] US Army. (2001, August). MANPRINT: An Approach to Systems Integration. Retrieved January 27, 2008, from http://www.manprint.army.mil/manprint/docs/mp-history.pdf

[7] US Army. (2001, August 15). What is MANPRINT? Retrieved September 1, 2005 from http://www.manprint.army.mil/manprint/docs/whatismanprint.pdf

[8] Wenger, T., Plott, B., & LaBay, S. (2006, July). Software User’s Manual for the Integrated Simulation Manpower Analysis Tool (ISMAT) (Version 1.1).

[9] Youngson, G., Baker, K., Kelleher, D., & Williams, S. (2003, November). Project Support Services for the Operational Mission and Scenario Analysis for Multiple UAVs/UCAVs Control from Airborne Platform - Phase I Summary Report (DRDC Toronto CR 2004-061).

Annex A The UAV Mission

The mission scenario chosen for this project is the scenario described in Kobierski’s report “Hierarchical Goal Analysis and Performance Modelling for the Control of Multiple UAVs/UCAVs from an Airborne Platform,” (DRDC Toronto CR 2004-063) and is included here for reference. The timeline was consolidated from three separate tables into one table here.

The mission scenario described in this annex forms the basis for an analysis of CP-140 Unmanned Air Vehicle (UAV) crewmember activities (goals and task interaction). This mission is set seven years in the future.

The scenario begins with a fictitious advanced briefing to Commonwealth Heads of Government Meeting (CHOGM) security staff, conducted in February 2011. Following this, a description of the situation on the day of the opening of the CHOGM is provided, as well as a brief overview of the one-hour scenario….

COMMAND AND CONTROL OF CP-140 UAV TEAM

The CP-140 is manned by a crew, which is augmented by two additional crewmembers who have responsibility for controlling UAV assets. These are the UAV Operator (UAV Op) and the UAV Pilot (UAV Plt). It is possible that these individuals may be CP-140 crewmembers who have been cross-trained to operate the Canadian Forces (CF) UAV fleet. The CP-140 in under the control of the Military Operations Centre in Halifax and the Medium Altitude Long Endurance (MALE) UAV is under the control the Regional Operations Centre (ROC), which is, for the purposes of this scenario, also located in Halifax. The CP-140 tactical crew consists of the Tactical Navigator (TACNAV), or mission commander, the UAV Operator and the UAV Pilot. The TACNAV occupies his or her normal position, and to the left of the TACNAV are the UAV Operator and Pilot. These two individuals occupy the Acoustic Sensor Operator (ASO) reconfigurable workstations of the modernized CP-140. The TACNAV has overall responsibility for the UAV mission, the UAV Operator is responsible for ensuring that the data and images are collected effectively and controlled for use in civilian court, and the UAV Pilot (who has the least complex role) is responsible for UAV flight path and air vehicle systems….

A BRIEF OVERVIEW OF THE SCENARIO

For the purpose of this scenario, the UAVs are controlled from the CP-140 Acoustic Sensor Operator (ASO) positions, and the UAV crew consists of the TACNAV, the UAV Operator occupying the ASO 1 position and a UAV Pilot occupying the ASO 2 position (the aisle seat). The rest of the CP-140 crew supports the mission. The scenario begins at 18:00 hrs, after the Aurora crew has received information that a terrorist threat to the CHOGM is possible and they are re-tasked to search for a vessel that is carrying a container the size of the KZO launch container (approximately 10 ft x 8 ft x 20 ft). Reports have suggested that the threat may come from a trawler-sized vessel. The vast

majority of the fishing fleet is operating under overcast conditions, approximately 100 nm offshore. Visual identification will require flight below the cloud ceiling. Two of the Canadian Patrol Frigate (CPF) VTUAVs are airborne and HMCS Halifax has just handed off control of one of these assets (VTUAV 1) to the CP-140 flight crew to assist in contact identification.

Two CF18s are scrambled and tasked to proceed to an area 20 nm south of St. John's and mount a combat air patrol.

Once the VTUAVs clear their mother ship, HMCS Halifax makes ready and launches the new MH. The mission is to investigate another concentration of vessels to the south. The ship's crew knows that recovery of VTUAV 1 will be necessary at approximately the same time that the MH returns, but the situation dictates that all three vehicles be airborne. Modification of the flight deck to accommodate the recovery of the MH and VTUAVs is the latest alteration to the vessel.

At approximately 18:40 hrs, contact is lost with VTUAV 1 as it approaches a vessel under investigation. The Aurora immediately launches three Mini UAVs and warns other airborne units to avoid the possible threat. The MALE UAV (using Inverse Synthetic Aperture Radar [ISAR] from medium altitude) and the Mini UAVs investigate the vessel, and at the same time HMCS Halifax makes best possible speed to the same location. VTUAV 2 is also directed towards the suspicious boat and control is passed to the CP-140 crew. At approximately 18:50 hrs, a Mini UAV transmits an image of men working on the foc'sle of the trawler. These individuals have exposed a large storage container. The CP-140 continues to covertly observe through the EO sensor of VTUAV 2 and Mini UAVs as the container is opened to expose a Jet Assist Take-Off (JATO) UAV. The CF18s are ordered to attack the now identified terrorist boat. Minutes later, the Lethal UAV is launched.

Communicating with the MALE UAV operator via a chat room, the crew provides the departure heading of the Lethal UAV and the MALE UAV operator initiates tracking. Observation of a second Lethal UAV on the terrorist boat heightens concern until a successful fighter attack is carried out. At 19:00 hrs, the scenario ends, although the mission is still ongoing. The Aurora crew initiate a search for the Lethal UAV, which is tracking randomly towards St John's.

Timeline	**Event**
18:00 hrs	The Aurora UAV crew is occupied with controlling VTUAV 1, which is investigating two contacts (Contacts 2 and 3); at the same time, the aircraft is transiting to observe two different fishing vessels (Contacts 1 and 4). Initial one-to-one data link control with VTUAV 1 was established prior to 18:00 hrs. The

	CP-140 is level at 4000 ft.
18:01 hrs	The UAV operator re-familiarises himself with the systems onboard VTUAV 1, including settings established by the CPF UAV crew. As a test of the system, he initiates an observation of a known contact in the direction of flight. The crew's third pilot occupies the vacated ASO 2 position and reconfigures this workstation to a STANAG 4586 configuration for flight control of the CPF's VTUAV.
18:02 hrs	The TACNAV plans the route for the Aurora, and requests that the pilots descend below the cloud, and turn and head towards the first contact at high speed. Non-Acoustic Sensor operator (NASO) 1 generates a GENTRACK on the target and directs the pilots for a homing from the stern until the EO operator gains contact. The flight crew works with the NASO 1 (AESO 1) who is using the onboard radar to clear the way ahead for the descent and at the same time search for the contact of interest. The NASO 2 configures the EO to begin a Charge Coupled Device (CCD) colour camera and an Infrared (IR) sensor search to classify and potentially identify the unknown contact once the aircraft descends below the cloud.
18:03 hrs	The NAVCOM completes his radio transmission, acknowledging the current tasking with MOC in Halifax.
18:04 hrs	The TACNAV and UAV operators work as a team to plan the route and search activities of VTUAV 1. The UAV operator is occupying the ASO 1 position and has configured the workstation to a STANAG 4586 standard for control of imagery. The TACNAV requests that the UAV Pilot direct VTUAV 1 to an initial heading of 300° true, maintain 800 ft Above Sea Level (**ASL**), and increase speed to the dash speed of 200 kts. The UAV Operator uses the Telephonics 1700B (Mark II) Radar to search for Contact 2. The TACNAV extrapolates the last known position, course (315° true) and speed to establish a datum. Most of the fishing vessels in the area are headed northwest into the wind with their nets deployed.
18:05 hrs	NASO 1 is fully occupied with updating the radar plot. At 15 nm from Contact 1, the Aircraft Captain (**AC**) reports that the aircraft is level at 800 ft.
18:06 hrs	The NAVCOM obtains additional information regarding the type of contact and potential threat the crew may encounter, updates the Electronic Support Measures (ESM) library and presets for chaff and flares.

18:07 hrs	The UAV Pilot begins to take stock of the fuel onboard VTUAV 1, potential landing pads (CPF, Hibernia oil drilling platforms, etc.), and refuelling locations. The pilot advises that the UAV will have at least two hours on-task and that a more refined time estimate will be available soon.
18:08 hrs	The EO Operator establishes contact with the first vessel to be investigated (Contact 1) and the flight crew plans an EO rig, which will allow effective observation and at the same time minimize the threat from surface to air missiles. The UAV Pilot and the TACNAV conclude that VTUAV 1 must eventually return to the CPF because there is no other suitable landing area in the vicinity.
18:09 hrs	The name and licence of Contact 1 are determined.
18:10 hrs	The flight crew reach the closest point of prudent approach and commence an arc around Contact 1. Using the name and licence of Contact 1, the NAVCOM accesses the Department of Fisheries and Oceans (DFO) online database for the East Coast to get a confirmation photo and history of this boat.
18:11 hrs	As the CP-140 circles Contact 1, NASO 2 continues to observe the boat using the EO suite.
18:12 hrs	The UAV Operator and TACNAV continue tracking VTUAV 1 towards Contact 2. While generally following the route to the datum, the course of VTUAV 1 is varied twice to allow for identification of two contacts near the route. NASO 2 reports that the nets on Contact 1 are just about to be streamed, and a large box-shaped object on the foc'sle is a large pile of crab traps. The TACNAV directs the crew to proceed to Contact 4. With a transit speed of 240 kts, the 62 nm distance is covered in approximately 16 minutes.
18:13 hrs	MOC advises the Aurora crew that the MALE UAV is able to assist in approximately 8 minutes. The crew is directed to contact the ROC. The Raytheon Sea Vue (Mark II) Radar of the MALE UAV is out of range. The UAV Operator asks Ordinance to prepare one Mini UAV for deployment. The TACNAV sets the operating height electronically for 1000 ft so that the tactical crew could deploy the Mini UAV from altitude and with minimum time delay to obtain video imagery from below the clouds. The Mini UAV is prepared in anticipation of deployment over Contact 4. The AC advises that Contact 1 has been identified as the Guppy from Portland, Maine, and he is turning the aircraft toward Contact 4. The TACNAV requests that the Aurora Pilot climb to 4000 ft in order to maintain the data link with VTUAV 1.

18:14 hrs	The NAVCOM confirms that the Guppy is not on any of the Vessel of Interest lists.
18:15 hrs	The CP-140 continues towards Contact 4. The pilot reports that the aircraft is level at 4000 ft.
18:16 hrs	NASO 1 uses the ISAR to scrutinise Contact 2. It is determined that although the length and breadth of Contact 2 match the search criteria, there is nothing unusual about the structure and this Contact is unlikely to be the terrorist vessel. Regardless, the decision is made to identify Contact 2 using VTUAV 1. VTUAV 1 changes course slightly to investigate Contact 2.
18:17 hrs	The NAVCOM requests an update on the air picture from the Halifax. Contact 2 is identified as the Dolphin from Miami, Florida. It is fishing legally. VTUAV 1 turns towards Contact 3 and level flight at 800 ft is maintained. With a momentary lull in the action as both the CP-140 and VTUAV are in transit, the TACNAV initiates a discussion with the AC to try and determine the location of the terrorist vessel. It is deemed that a terrorist vessel would have turned towards St. John's, the site of the CHOGM. At the same time, MOC asks the CP-140 to also investigate a suspicious boat 20 nm north of VTUAV 1. MOC recommends caution when approaching this boat. A datum for Contact 5 is plotted on the computer.
18:18 hrs	As VTUAV 1 is already closer to the new target vessel, the TACNAV directs the UAV Pilot to investigate Contact 5 before Contact 3, once investigation of Contact 2 is complete.
18:19 hrs	VTUAV 1 has completed investigation of Contact 2 and turns towards Contact 5. The VTUAV 1 time on-task is approximately 2 hours and 10 minutes; it must return to the CPF. Coordination will be required because that will be the approximate time that the MH will require refuelling. The deck cycle has been interrupted due to the urgent nature of the mission. The remaining VTUAV 2 time on-task is lengthy considering the recent launch, and will not require refuelling for many hours.
18:20 hrs	The UAV Operator begins to create a surface plot of the area around the datum as VTUAV 1 transits towards the new search area. The Aurora continues towards Contact 4 at 4000 ft. ROC advises the NAVCOM that the MALE UAV has completed the search in his area and is standing by to assist the CP-140 on the eastern boundary of the Aurora's area.
18:21 hrs	The TACNAV requests that the MALE UAV enter the CP-140 area, but remain at 7000 ft or above, whereas the CP-140 will remain at 6000 ft or below. The MALE UAV is to investigate Contact 3.

18:22 hrs	With the combined Radar data from VTUAV 1 and the Aurora, the TACNAV quickly builds a plot of contacts in the area of Contact 5 and selects three vessels of which one could be the terrorist boat. The TACNAV directs VTUAV 1 to investigate the first of the three boats and requests that the MALE UAV use its ISAR radar to image the second of the three boats while heading to Contact 3.
18:23 hrs	The TACNAV then directs his attention towards Contact 4.
18:24 hrs	NASO 1 has a good GENTRACK on Contact 4 and directs the pilot for the homing down the Mean Line of Advance (MLA).
18:25 hrs	The UAV Pilot turns VTUAV 1 towards the first boat (designated Contact 5) and then concentrates on establishing a waypoint near this boat, which will allow a discreet approach. The pilot is aware that the VTUAV is relatively noisy and an approach from east-southeast will keep the vehicle downwind. He also considers that the overcast conditions will give no advantage to approaching with the sun behind the vehicle. The UAV Pilot decides that a waypoint on a relative bearing of 120° true at 5 nm from the contact is best, although this requires a diversion from the direct route and a 90 left turn to approach the boat. The UAV Pilot notes that the boat is heading west-northwest like the other fishing vessels. The UAV Pilot established a transit speed of 120 kts.
18:26 hrs	The TACNAV presets the waypoints and search pattern for the Mini-UAV (automatic actions to be taken after launch if the UAV Pilot cannot gain control of the vehicle).
18:27 hrs	The UAV Pilot brings VTUAV 1 as high as possible without entering the clouds.
18:28 hrs	After reviewing the Contact history (from the original portion of the fisheries patrol), the TACNAV advises the UAV Pilot and UAV Operator that one of the three boats in that group should be the fishing boat “Trust Me”.
18:29 hrs	The AC tells the TACNAV that the aircraft is two minutes back from Contact 4 and he is slowing the aircraft down to a speed that will allow deployment of a Mini UAV. Using the estimates of the wind generated by the Embedded Global Positioning Systems/Inertial Navigation Systems (EGIs), the TACNAV makes a final determination of the Pickle Point and passes this to the pilot.

18:30 hrs	The ROC advises that the ISAR imagery of the second boat should be available in two minutes.
18:31 hrs	The flight deck crewmembers review the online checklist for Airborne Mini UAV Deployment.
18:32 hrs	The UAV Operator reports to the TACNAV and UAV Pilot that he has verified the identity of the “Trust Me” from Come-By-Chance, Newfoundland, and recommends that the pilot resume course to the third boat suspected to be Contact 5. The UAV Pilot provides VTUAV 1 with commands to head towards a waypoint established at 5 nm from the unknown boat. The UAV Pilot verifies that VTUAV 1 is operating within normal parameters and prepares to take control of the Mini UAV once it has dropped to 1000 ft, is deployed from the A-size parachute stabilised container, and is established in straight and level flight. The initial heading will be into the wind, as pre-programmed prior to deployment. NASO 2 accesses the ROC image server, extracts the MALE UAV ISAR image and compares it to the last VTUAV contact. He advises the TACNAV that both the MALE UAV and VTUAV 1 have investigated the same boat. The NAVCOM advises the ROC of the mix-up and requests imaging of the second boat.
18:33 hrs	Upon reaching the UAV Fly-to-Point, the CP-140 automatically releases the Mini UAV. The AC verbally advises that the Mini UAV has been deployed over Contact 4, and both the TACNAV and UAV Pilot verify this with their display symbology. The Aurora is turned towards the area of Contact 5 to assist with finding this boat. The crew track the descent of the Mini UAV over Contact 4 and wait for an uplink of a video image. On queue, at 1000 ft, the Mini UAV transmits that it has established level flight, into wind, and is standing by for control signals. The UAV Pilot takes control of the Mini UAV and verifies its serviceability.
18:34 hrs	The TACNAV directs the AC to maintain the current altitude (4000 ft). The UAV Pilot, with assistance from NASO 1, turns the Mini UAV in the direction of Contact 4 and, while accommodating for the wind, establishes a track directly towards the boat. He also initiates an enroute descent to 300 ft. At this time, he checks on the progress of VTUAV 1 and finds that the vehicle is proceeding as directed towards the waypoint. NASO 1 advises that the Mini UAV is within 2 nm of the contact, and at the same time, the UAV Operator advises that EO is active, although the boat is not in the Field-Of-View (FOV).

18:35 hrs	NASO 2 reports to the TACNAV that the MALE UAV imaging of the second boat in the vicinity of the new datum has been completed. Although the boat could not be identified, it was determined to be a small trawler and there did not appear to be any container shaped structure on the decks. The TACNAV rejects this boat as a possible terrorist threat and directs the MALE UAV to attempt imaging of the third boat. Having established that the Mini UAV deployed over Contact 4 is functioning nominally, the UAV Pilot passes control of the flight path to the UAV operator, but still maintains an overview of the UAV progress to assist if required. Manual flight control is a reversionary mode, however, the pilot would have to have been following the UAV activities in order to use this reversionary mode effectively, if it becomes necessary. The UAV Pilot also monitors the progress of VTUAV 1. The UAV Operator uses the point and click control features of the interface to establish a sea level waypoint at the location of Contact 4. The crew does not have to concern themselves with the data link because the Mini UAV transmits omni-directionally. With the UAV FOV presented on the UAV Operator's tactical plot (tacplot), the operator drags the FOV trapezoid over the radar contact and zooms in using the UAV's EO suite. The Mini UAV flies directly towards the unsuspecting fishers.
18:36 hrs	The UAV Operator records a high-quality video image of Contact 4. He uses the onboard database and support from the ROC database to determine that the boat is a known vessel, "Master", but is fishing illegally in a zone that does not open for another 5 hours and 27 minutes. The crew has just hauled in the nets and the rear deck is awash in fish. The TACNAV requests that NASO 1 update the position of Contact 3 and all three boats in the vicinity of Contact 5. The TACNAV then directs the NAVCOM to access the online "Fishing Violation" report and action it.
18:37 hrs	The Mini UAV over Contact 4 is set on autonomous Operations to report automatically all information required to prosecute the vessel "Master" in court. Video and location information is recorded onboard the Aurora. The Aurora crew direct their attention to the remaining unknown boat in the vicinity of the new datum, which is determined (by the process of elimination) to be Contact 5 and, thus, has a higher priority than the fishing violator.
18:38 hrs	The crew determines that with the approach path planned, VTUAV 1 will pass near a small fishing boat at approximately 2 miles from Contact 5. The crew decides that they will observe this boat enroute to their primary objective. The CPF advises that VTUAV 2 is investigating a small group of fishing vessels to the south of the VTUAV 1 position (which they know from the LINK-11 picture transmitted by the CP-140). The MALE UAV completes imaging of Contact 3 and attempts to image Contact 5.

18:39 hrs	NASO 2 reports to the TACNAV that the ISAR imagery of Contact 3 from the MALE UAV shows that it is very similar to the previous boat studied and that there were no suspicious container shapes on the decks. The TACNAV decides that further investigation of Contact 3 is not necessary and turns to the surface plot to determine how to employ the MALE UAV. He begins to resize the area displayed on his workstation. The UAV Operator reviews the data being collected by the Mini UAV deployed earlier and finds that good video was collected up until the fishers spotted the Mini UAV and then covered the deck with a tarpaulin. The boat had turned south with the Mini UAV in a holding pattern approximately ½ nm aft. The NAVCOM reports the fishing violator to the DFO, and advises where video and location information can be found via a secure chat room. The UAV Pilot monitors the progress of VTUAV 1 as it flies towards the waypoint.
18:40 hrs	VTUAV 1 reaches the waypoint and turns towards Contact 5. The EO sensor shows only the small fishing boat 3 miles from Contact 5.
18:41 hrs	At three miles from Contact 5, the VTUAV maintains 800 ft to observe the object of their search. The UAV Operator then swings the EO over to photograph the fishing boat they are passing. The fishers onboard are looking and pointing at the UAV. The ROC reports to the NAVCOM that the ISAR imagery from Contact 5 shows a very unusual structure on the bow of the vessel. Strong returns are obtained from large metal corners that are not common on the other fishing boats. The image of the small fishing boat is the last image recorded when the UAV Pilot reports that VTUAV 1 has stopped transmitting data. Moments later NASO 1 switches the radar to Air-to-Air and reports that radar contact with VTUAV 1 has been lost.

18:42 hrs	The TACNAV contacts the ROC and requests that the MALE UAV keep imaging contact 5. The TACNAV quickly realizes that someone must take control of the situation, the Mini UAVs onboard the Aurora and VTUAV 2 are the only source of additional information. The MH has been vectored towards the scene, but will not arrive for at least 25 minutes. The crew assesses that they are the most capable platform on the scene at the current time. The CP-140 assumes Shipborne Aircraft Controller (SAC) duties. The CPF advises that it can vector VTUAV 2 towards Contact 5 and complete a handover to the CP-140. The VTUAV is 20 nm from Contact 5 and the CPF advises that the CP-140 crew should take control of this asset in one minute. MOC also advises that the CF-18s have been tasked to close at maximum speed. This section of hornets is to report momentarily on their weapons load and weapon of choice to render Contact 5 incapacitated on the designated frequency. The NAVCOM sets the appropriate radio. The CP-140 crew is unclear as to why the VTUAV was lost. A review of the last frames of video does not help, because the small fishing boat the crew was observing at the time did not appear to take any overt action. The TACNAV determines that identification of Contact 5 must be performed as soon as possible to avoid sinking a potentially neutral boat. The TACNAV advises both the UAV Operator and the UAV Pilot to terminate the Mini UAV over Contact 4.
18:43 hrs	The TACNAV requests that the AC increase speed to Velocity Never To Exceed (VNE) or 'go Buster'. The current altitude (4000 ft) will keep the aircraft above cloud and hidden from EO/IR missiles. Transmissions are to be secure from this point on. Full Electronic Warfare (EW) policies are to be adhered to. The TACNAV briefs the crew that he intends to over fly the contact and deploy three Mini UAVs and then establish an orbit, which would maximize reception from the Mini UAVs. He requests that the NAVCOM transmit these intentions to the CF-18s and the MOC. Preliminary imaging data are received from the MALE UAV, which show a medium sized fishing vessel with an unusual structure near the bow. The boat is maintaining a steady course north-northeast.
18:44 hrs	The pilot advises the crew that the aircraft is 2 minutes back. The crew takes control of VTUAV 2 and vectors it directly towards Contact 5, at an altitude of 2500 ft (above the clouds). Estimated Time of Arrival (ETA) at Contact 5 is 8 minutes. The TACNAV asks Ordnance to load three Mini UAVs, and set them to establish level flight at 1000 ft, 800 ft and 600 ft. He then asks the UAV Pilot to use the two lowest Mini UAVs to initiate cloverleaf patterns about the contact with a descent to 200 ft and 400 ft on each pass. The highest Mini UAV is to be used for a circular pattern about the contact at 800 ft. Wind and mutual separation must be accommodated, however, maximizing viewing time is essential. The UAV Operator advises that he will transmit all relevant photos and video images via the net chat room.

18:45 hrs	The UAV Pilot recommends to the TACNAV that a Mini UAV be deployed to investigate the site where contact was lost with VTUAV 1. The TACNAV concurs, puts a waypoint on the Electronic Horizontal Situation Indicator (EHSI) and requests the AC to over-fly this waypoint after deploying the first three Mini UAVs. Ordnance advises that another Mini UAV for a 600 ft search altitude is being prepared. NASO 1 conducts a radar search of the area, finds a weak contact near the point that VTUAV 1 was lost, and provides this new information to the TACNAV, who updates the waypoint provided to the pilot moments before. The AC slows the CP-140 down to Mini UAV launch speed.
18:46 hrs	The TACNAV deploys three Mini UAVs at five-second intervals. The AC then turns the aircraft towards the next waypoint and advises “one minute back”.
18:47 hrs	A fourth Mini UAV is deployed as the Aurora reaches the assigned waypoint over the downed VTUAV. The first three Mini UAVs appear on the tacplot within 10 seconds of each other and start transmitting video and data. The Hornets check in with the Aurora and advise that they are prepared to attack the vessel with precision guided weapons. The NAVCOM advises the fighters to stand-by while visual confirmation of the threat is acquired.
18:49 hrs	The Mini UAVs show images of a fishing boat transiting in the direction of the swell and across the wind lines. The relative wind is at 90° off the bow to port.
	As the Mini UAVs approach the boat, men can be seen moving on the deck and a container is shown on the bow of the boat. The Mini UAV that was launched over the downed VTUAV reports that it has established straight and level flight and is awaiting instructions. The UAV Pilot tasks this Mini UAV with a circular search pattern about the intermittent radar contact at the same location. The UAV Operator notes the instructions and opens a fifth viewing window to monitor imagery of the downed VTUAV.
18:50 hrs	The UAV Pilot takes control of the first Mini UAV at the scene and using the controls available to him, breaks off the cloverleaf pattern to fully investigate the structure on the boat. The Aurora crew recognizes a medium range JATO UAV mounted inside a transportation container. Both sides of the container are open and men are removing flags and battens from the UAV. The CP-140 crew also observes what appears to be a second container mounted mid-ships. This structure is not clearly visible.

18:51 hrs	The TACNAV and UAV Operator immediately realize that this is the Lethal UAV they are searching for and that the JATO UAV is pointing into the wind and is being readied for launch. It appears that the personnel on the vessel are aware that they are being observed and a sense of urgency demonstrated by their actions indicates that they know that time is of the essence, considering their overt actions against VTUAV 1. The UAV Operator scrutinizes the suspicious structure mid-ships concludes that it is probably a second Lethal UAV container.
18:52 hrs	The TACNAV asks the UAV Pilot if it would be possible to crash a Mini UAV into the container. The answer is that the control interface and associated time delays would make it impossible to hit this moving target. However, use of the laser designator on board a Mini UAV would allow targeting for a missile from a CF-18. The TACNAV responds by issuing a Flash message requesting an immediate attack by the flight of Hornets. The TACNAV requests that the CP-140 over-fly the boat once more at 4000 ft to accommodate the launch of the laser designator Mini UAV. Although these Mini UAVs are much more expensive than the standard EO Mini UAVs, it is clear to the TACNAV that the crew must have one available on an as required basis, and the time required to deploy this device can be saved by launching it now. The TACNAV requests that the laser designator Mini UAV be put into a holding pattern about a waypoint he inserts on the tacplot east of Contact 5. The Hornet Lead confirms the instructions and pre-positions for the attack. The NAVCOM instructs the MALE UAV to remain in the southwest sector of the area until the fighters have returned to Combat Air Patrol (CAP) altitude.
18:53 hrs	The TACNAV advises NASO 1 that the Lethal UAV may be launched at any time, and that they are to track the UAV for as long as possible. NASO 1 switches the radar to Air-to-Air mode. The AC suggests that once the Lethal UAV is clear of the terrorist boat, they could establish a trail formation and visually track the UAV inbound to St. John’s. At the same time, he advises the crew that the aircraft is one minute back from the launch point for the laser designator Mini UAV.
18:54 hrs	The laser designator Mini UAV is launched and the CP-140 retreats to a safe distance from the terrorist vessel. The tacplot indicates the position of the newest Mini UAV.
18:55 hrs	The UAV Pilot establishes control of the laser designator Mini UAV and directs it to a holding pattern at the TACNAV established waypoint. The laser designator is slaved to Contact 5. At the same time, the TACNAV maintains reconnaissance of the terrorist vessel using the previously launched Mini UAVs. VTUAV 2 is directed southeast of Contact 5, to hold away from the Hornet’s intended track.
18:56 hrs	The Lethal UAV is launched from the terrorist boat. This is observed by the CP-140 UAV crew. NASO 1 commences tracking of the Lethal UAV, but loses contact shortly after it turns to the north. A Flash Message is sent to MOC via SATCOM.

18:57 hrs	The crew realize that capture of the terrorist would be beneficial; however, they are concerned about the suspicious container remaining unidentified on the boat. At the same time, the fighters report that they will be ready to commence an attack in one minute. The TACNAV requests that the fighters continue but not arm their weapons. At the same time, the TACNAV requests more information from the UAV Operator. The UAV Operator has turned to Mini UAVs and is diving them towards the boat. The UAV Pilot has descended VTUAV 2 below cloud, and is observing the boat from a range of 3 miles downwind. The video clearly shows that the terrorists are readying a second Lethal UAV and the TACNAV directs the Hornets to “go hot”. Although the fighter pilots are using the “big sky” approach to collision avoidance, the CP-140 crew dive the Mini UAVs to just above the wave tops to avoid a midair collision. The VTUAV anti-collision strobe light is set to ON as the fighters pass. Although the crew havs lost radar contact with Lethal UAV, they believe that the only course of action is to begin a search for this UAV.
18:58 hrs	The terrorist boat is destroyed with one GBU-16, a 1000 lb Laser Guided Bomb (LGB). The TACNAV begins the process of setting up a search pattern for the Lethal UAV while the UAV Operator sets the Mini UAVs to self-directed mode.
18:59 hrs	The CP-140 UAV crew coordinates with the CPF UAV Controller for the return of VTUAV 2. Although the MALE UAV is able to provide an initial track for the Lethal UAV, it also loses contact. The scenario ends.

EPILOGUE

Based on direction provided by the CP-140 crew, the Modernized CF-18 aircraft shot down the Lethal UAV, which was en route to St. John’s harbour. The target was determined to be the British destroyer. The RCMP apprehended two individuals who were erecting a laser designator on the slopes of Signal Hill. This laser designator would have provided final control signals to the Lethal UAV to ensure maximum damage.

Annex B Goal ID, OSD ID, and Task ID Mappings

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
All Operators							
2.6.3 identification of known terrorist units							
7.2.7 MALE UAV systems are monitored and managed							
MC							
2.1.1 radar plot of an area of interest is current	4-9	164 166 167	TN TN UP	2 2 3	2 2 7	21.12.11 21.12.12 27.6.5	
3.5.1 command & control of tactical situation is assessed	12	192	TN	3	10	27.12.1	
3.5.2 a determination of the SAC (OSC) is completed	12	196	TN	3	10	27.12.3	
5.1.3 relevant rules of engagement are reviewed	8	152	TN	1	2	4.1.13.5	
5.2.1 overt actions of terrorist unit personnel are observed	3	490 491 492	UO TN UP	3 3 3	42 42 43	27.29.1 27.29.12 27.29.13	
5.3.1 potential weapons onboard terrorist unit	6	414	TN	3	30	27.20.11	
5.3.8 risk to neutral units	6	218	TN	3	6	27.6.17	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
5.5.2 selection of best units to counter to terrorist threat	5-18	436 526	TN TN	3 3	34 46	27.23.14 27.32.1	
5.5.6 selection of best offensive system(s)	5-20	420 465 466 467 500 541	TN UO TN UP TN TN	3 3 3 3 3 3	30 38 38 39 42 46	27.20.8 27.27.7 27.27.8 27.27.9 27.29.7 27.32.12	
5.6.3 tasking message has been transmitted	6-9	538 550	TN TN	3 3	50 46	27.33.11 (task name is wrong) 27.33.4	
5.7.8 damage report provided to friendly unit	8	567	TN	3	50	27.34.10	
6.4 terrorist's potential location	5-30						
6.8.1 the need for contingency plans is addressed	30	120	TN	3	2	27.2.1	
6.8.2 contingency plans are created	10	150	TN	1	2	4.1.13.2	
6.8.3 contingency plans are discussed	10	151	TN	1	6	4.1.13.9	
7.3.1.2 Mini UAV search pattern is planned	5-15	340 206 260 262 354 235	TN TN UP TN UP TN	1 2 2 2 2 3	22 10 11 10 27 10	4.3.9.10 21.18.1 21.19.2 21.19.3 21.21.17 27.11.8	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.3.1.10 crew is briefed on use of Mini UAVs	18-20	236 542 561	TN TN TN	3 3 3	10 46 46	27.11.17 27.32.6 27.34.2	
7.3.1.11 crew have been requested to launch Mini UAV	8	452	TN	3	34	27.25.10	
7.3.8.1 previous minutes of video are reviewed	20	588	TN	2	46	21.35.11	
9.3.2.2 request for surface plot is passed to ROC	5	304	TN	1	14	4.2.7.10	
9.3.2.3 fighter aircraft are directed to attack threat	14	438	TN	3	34	27.24.5	
9.4.1.5 information of a general nature	3-35	124	TN	3	2	27.2.4	
PO							
2.1.4 tactical plot icons are current	8	360 442	UO UO	1 1	18 30	4.2.16.10 21.23.11	
5.6.4 tasking message has been acknowledged	9	537 539	UO UP	3 3	50 51	27.33.10 27.33.12	
7.1.4.2 VTUAV EO sensor is used for a test observation	10	168	UO	1	10	4.1.14.16	
7.1.5.6 VTUAV EO images are monitored	25	434	UP	2	19	21.23.17	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.9.3 initial system settings on VTUAV are reviewed	10	164 166	UP UO	1 1	11 6	4.1.14.17 4.1.14.9	
7.3.7.5 Mini UAV image file is stowed	14	223	UO	3	10	27.8.7	Not in trc
9.4.1.3 identification and activities of contact *these OSD IDs refer to goal 9.4.1.5 in the OSD	3-20	362 392 444 424 268 296 308 366 390 469 418 436 438 442 454 502 514 524 527 530 536 555 560 561 617 623 624 177 410 411 416 417 418 427 460* 494	UO UO UO UO TN UP UO UO UO TN UP UO UP UO UO UO UO UO UP UO UO UO TN UO UO TN UO TN UO TN UO TN UP UO TN UO	1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3	18 30 30 26 6 15 14 14 22 30 31 18 19 18 30 34 38 42 43 42 42 38 38 38 50 50 50 6 30 30 30 30 31 34 38 42	4.2.16.15 4.2.28.7 4.2.26.2 4.3.8.1 21.17.21 21.20.4 21.20.11 21.22.5 21.24.11 21.24.23 21.28.4 21.23.6 21.23.8 21.23.11 21.29.8 21.31.4 21.31.12 21.31.23 21.31.25 21.31.27 21.34.2 21.32.13 21.32.17 21.32.18 21.38.11 21.38.15 21.38.16 27.5.19 27.20.2 27.20.3 27.20.6 27.20.5 27.20.7 27.23.2 27.27.2 27.29.3	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
		530* 531* 532* 545 546 547	UO TN UP UO TN UP	3 3 3 3 3 3	46 46 47 46 46 47	27.32.2 27.32.3 27.32.4 27.32.10 27.32.9 27.32.11	
VO							
6.9.1 VTUAV piloting aspects are studied	20	204	UP	1	7	4.1.14.11	
7.1.3 VTUAV flight path is monitored	4-continuous	162 220 354 286 372 378 436 454 474 202 232 242 316 492 652 654 660 132 138 272 527	UP UP UP UP UP UP UP UP UP TN UP UP UP TN UP UP TN UP UP UP UP	1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 3 3 3 3	7 11 15 19 19 27 31 35 35 6 7 11 15 26 39 43 42 3 3 19 43	4.1.14.12 4.2.3.16 4.2.6.37 4.2.16.27 4.2.16.26 4.2.15.2 4.2.26.13 4.2.27.1 4.2.18.2 21.17.16 21.17.9 21.17.26 21.20.15 21.26.16 21.27.2 21.27.11 21.36.1 27.4.2 27.4.7 27.38.9 27.31.2	
7.1.5.6 VTUAV EO images are monitored	25	434	UP	2	19	21.23.17	Also a PO goal
7.1.9.2 initial system checks on VTUAV are conducted	12-30	146 270 271	UP UO UP	1 3 3	7 8 19	4.1.14.15 27.38.7 27.38.8	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.9.4 VTUAV systems are monitored	6-cont	256 372 135	UP UP UP	2 2 3	11 15 3	21.17.31 21.22.8 27.4.5	
7.3.1.8 Mini UAV route is plotted	10-18	505 555	UP UP	2 3	35 51	21.31.7 27.34.5	
7.3.7.2 initial system checks on Mini UAV are conducted	4	358	UP	2	27	21.21.16	
7.3.7.3 Mini UAV systems are monitored	9-cont	452 460	UO UP	2 2	30 31	21.29.16 21.29.7	
7.3.7.4 Mini UAV systems are managed	5	458	UP	2	35	21.29.11	
9.4.1.1 VTUAV refuelling location is transmitted	5	248	UP	1	11	4.1.21.8	
9.4.1.2 VTUAV calculated time on task is transmitted	5	260	UP	1	11	4.1.21.15	
9.4.1.4 specific information regarding a UAV	3-20	490 128 216 218 236 238 244 250 252 226 228 416 476 477 487 490	UP UP UP UO UP UO UO UP UO TN UO UP UP TN UP UO	1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	35 3 7 6 11 10 10 11 10 10 10 31 19 18 23 22	4.2.29.6 21.12.3 21.17.8 21.17.14 21.17.10 21.17.15 21.17.24 21.17.28 21.17.30 21.18.6 21.18.7 21.28.2 21.26.2 21.26.10 21.26.7 21.26.9	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
		644 214 215 216 240 273 290 298 350 395 396 397 389 432 433 434 580	UP UO TN UP TN UP UP UP UO UO TN UP UO TN UP UO UP	2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	39 6 6 7 14 19 15 19 26 26 26 27 30 34 35 34 55	21.27.13 27.6.14 27.6.15 27.6.16 27.11.13 27.38.10 27.14.4 27.14.17 27.17.17 27.18.8 27.18.7 27.18.9 27.22.17 27.23.6 27.23.7 27.23.8 27.36.8	
2.3.2 location of friendly units		X					Not in OSD
2.3.4 list mission activities of friendly units		X					Not in OSD
2.4.2 location of neutral units		X					Not in OSD
2.5.2.1 location of all unknown unit icons on tactical plot	6-16	168 234 222 584	TN TN TN TN	2 2 2 2	2 6 10 46	21.12.13 21.17.20 21.18.14 21.35.9	
2.5.2.2 relative location of own position to unknown units		X					Not in OSD
2.6.2.1 location of all known terrorist unit icons on tactical plot		X					Not in OSD

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
2.6.2.2 relative location of own position to known terrorist units		X					Not in OSD
6.4.1 the probable position of the terrorist vessel	5-30	456 458 460 464 466 468	TN UO UP TN TN TN	1 1 1 1 1 1	34 34 35 34 34 34	4.2.30.8 4.2.30.6 4.2.30.4 4.2.30.15 4.2.30.14 4.2.30.13	
6.4.4 search area is appropriate for the current situation	15	662	TN	2	42	21.36.2	
6.4.5 display area on workstation is appropriate	12	664	TN	2	42	21.36.3	
2.6.1 workstation is formatted to display the tactical plot		X					Not in OSD
4.1.5 latest position of all unknown contacts is plotted	8-15	282 390	UO UO	1 1	14 30	4.2.6.1 4.2.28.8	
4.1.10 search plan for airborne threat is produced	25	570	TN	3	50	27.35.4	Not in trc
4.2.5 contact is sought using UAV radar	10-cont	375 380	UO UO	1 1	26 26	4.2.17.5 4.2.17.6	
4.2.6 contact is visually sought using UAV EO suite		X					Not in OSD

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.2.1 VTUAV heading has changed to a new heading	5-cont	218 352 284 296 370 376 384 400 434 452 470 196 264 292 314 485 640 137 524	UP UP UP UO UP UP UP UP UP UP UP UP UP UP UP UP UP UP UP	1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 3 3	11 15 19 14 19 27 27 31 31 31 35 7 11 15 15 23 39 3 43	4.2.3.5 4.2.6.38 4.2.16.28 4.2.16.3 4.2.16.25 4.2.15.1 4.2.15.6 4.2.26.23 4.2.26.14 4.2.27.2 4.2.18.3 21.17.5 21.17.33 21.20.2 21.20.10 21.26.14 21.27.1 27.4.6 27.31.1	
7.1.2.2 VTUAV altitude has changed to a new altitude	5-6	240 248	UP UP	2 2	11 11	21.17.11 21.17.27	
7.1.2.4 VTUAV autopilot set to autonomous mode	4	579	UP	3	55	27.36.7	
7.1.2.5 VTUAV transitions to a hover	5	554	UP	3	51	27.33.19	
7.1.4.1 VTUAV EO sensor settings are optimized	6-30	148 178 486 140	UO UO UO UO	1 2 2 3	6 6 22 2	4.1.14.8 21.15.5 21.26.12 27.4.12	
7.1.5.4 VTUAV EO zoomed in on a portion of boat	7	428	UO	2	18	21.23.1	Not in trc

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.5.5 VTUAV EO used to record images of contact	12-cont	430 431 145	UO UO UO	2 2 3	18 18 2	21.23.3 21.23.4 27.4.11	
7.1.5.7 VTUAV EO image file is stowed	10	480	UO	2	22	21.26.11	
7.1.6 VTUAV radar is configured		X					Not in OSD
7.1.7.1 VTUAV radar is used to search for lost contact	14-60	222 126	UO UO	1 2	10 2	4.2.3.18 21.12.8	
7.1.7.2 VTUAV radar is used to vector another asset		X					Not in OSD
7.1.7.3 VTUAV radar is used to GENTRACK contact	4-10	351 374 200 258	UO UO UO UO	1 1 2 2	14 26 6 10	4.2.6.40 4.2.17.4 21.17.4 21.17.35	
7.1.9.1 VTUAV data up-link is maintained	12-cont	144 145 122	UO UO TN	1 1 2	6 6 2	4.1.14.7 4.1.14.6 27.2.2	
7.3.1.3 Mini UAV waypoint is inserted	3-10	224 288 290 462 294 303 360 449 479	TN TN TN UO TN TN TN ? TN	2 2 2 2 3 3 3 ? 3	10 22 22 34 14 18 26 ? 38	21.18.4 21.19.13 21.19.14 21.29.12 27.14.11 27.14.19 27.19.8 ? 27.28.12	
7.3.1.12 Mini UAV opening height is set	7	343	TN	1	22	4.3.9.17	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.3.2.1 Mini UAV heading has changed to a new heading	6-8	356 422 335 337 339 385 510	UP UP UP UP UP UP UP	2 2 3 3 3 3 3	31 31 23 23 27 31 43	21.21.15 21.28.8 27.17.1 27.17.11 27.17.15 27.22.3 27.30.3	
7.3.2.2 Mini UAV altitude has changed to a new altitude	22	425	UP	2	31	21.28.21	
7.3.2.4 Mini UAV altitude change has been initiated	6-8	424 553	UP UP	2 3	31 51	21.28.22 27.33.18	
7.3.2.5 Mini UAV automatic over-flight function is initiated	6-10	466 506	UO UP	2 2	34 39	21.29.14 21.31.19	
7.3.2.6 Mini UAV is set to autonomous operations	7-45	544 572	UO UO	2 3	42 54	21.34.10 27.36.6	
7.3.2.7 Mini UAV initiates a pre-planned route about a contact	5-8	336 338 340 386 512 518	UP UP UP UP UP UP	3 3 3 3 3 3	23 27 27 31 43 47	21.17.2 27.17.13 27.17.4 27.22.4 27.30.4 27.30.8	
7.3.2.8 Mini UAV initiates a self-destruct manoeuvre	6	224	UP	3	11	27.8.8	Not in trc
7.3.2.9 manual control of Mini UAV is initiated	4	399	UP	3	27	27.18.11	
7.3.2.10 Mini UAV is manoeuvring about contact	14-cont	400 424	UP UP	3 3	31 35	27.18.12 27.20.12	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.3.3.1 Mini UAV symbol has appeared on the surface plot	2-23	346 348 319 320 321 362 363 364 482 483 484	TN UP TN UO UP TN UO UP TN UO UP	2 2 3 3 3 3 3 3 3 3 3	26 27 22 22 22 26 26 27 38 38 39	21.21.11 21.21.10 27.15.7 27.15.6* 27.15.8 27.19.7 27.19.6 27.19.9 27.28.13 27.28.11 27.28.16	
7.3.3.2 Mini UAV is in descent following deployment	5	350	UP	2	27	21.21.12	
7.3.3.3 Mini UAV is following the planned flight path	Cont	508 342 387 514 519	UP ? UP UP UP	2 ? 3 3 3	39 ? 31 43 47	21.31.20 ? 27.22.9 27.30.5 27.30.9	
7.3.3.4 Mini UAV is establishing level flight	5-6	352 426	UP UP	2 2	27 31	21.21.13 21.28.20	
7.3.3.5 Mini UAV is autonomously following contact	13	592	TN	2	46	21.35.15	
7.3.4.1 Mini UAV EO sensor settings are optimized	10	345 346 347 388 516	UO UO UO UO UO	3 3 3 3 3	22 22 26 30 42	27.17.5 27.17.10 27.17.14 27.22.2 27.30.2	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.3.5.2 Mini UAV EO sensor is used to study a contact	4-cont	521 522 586 591 380 381 382 402 403 404 405 406 407 425 560 564 565 566 584	UO UP TN TN UO TN UP UO TN UP UO TN UP UO UO UO TN UP UO	2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	42 39 46 46 26 26 27 30 30 31 30 30 31 30 46 50 50 51 54	21.31.21 21.31.18 21.35.10 21.35.14 27.18.4 27.18.5 27.18.10 27.18.15 27.18.14 27.18.13 27.18.18 27.18.17 27.18.16 27.20.13 27.34.3 27.34.9 27.34.8 27.34.7 27.36.13	
7.3.5.4 Mini UAV EO zoomed in on a portion of boat	12	518	UO	2	38	21.31.15	
7.3.5.6 Mini UAV EO sensor is used to track a contact	14-20	375 376 377 520	UO TN UP UO	3 3 3 3	26 26 27 46	27.18.1 27.18.2 27.18.3 27.30.7	
7.3.5.7 Mini UAV EO is used to record high definition images	8-15	360 510 519 520	UO UO UO UO	2 2 2 2	14 34 38 38	21.22.1 21.31.8 21.31.16 21.31.17	
7.3.5.8 Mini UAV FOV trapezoid is over contact	5	464	UO	2	34	21.29.13	
7.3.5.9 Mini UAV EO video recording is operating	9	392	UO	3	30	27.22.8	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.3.5.10 EO images are organized on desktop	Cont	463	TN	3	38	27.27.4	
10.1.2.1 MC workstation is configured	10	154	TN	1	2	4.1.18.1	
10.1.2.2 VO workstation is configured	10	160	UP	1	7	4.1.18.7	
10.1.2.3 PO workstation is configured	10	156	UO	1	6	4.1.18.12	
4.4 identification of contacts (auto)		X					Not in OSD
4.4.5 crew identifying vessel using UAV EO suite	5-cont	358 389 440 500 523 528	UO UO UO UO UO UO	1 1 1 2 2 2	18 26 30 34 42 42	4.2.16.8 4.2.28.9 4.2.26.10 21.31.38 21.31.22 21.31.26	
4.4.6 ISAR imagery is downloaded and analysed	6	610 151	? TN	? 3	? 6	? 27.5.11	
4.4.7 UAV images of boat are compared with database	8-14	362 511	UO UO	2 2	14 34	21.22.2 21.31.10	
4.4.8 crew classify vessel using UAV EO suite	5-12	364 512	UO UO	2 2	14 34	21.22.3 21.31.11	
4.4.9 legality of fishing boat activities	6-14	535 589	UO TN	2 2	42 46	21.34.1 21.35.12	
4.4.10 contact can be identified	4	590	TN	2	46	21.35.13	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.1 VTUAV navigation is conducted (manual)		X					Not in OSD
7.1.1.1 VTUAV route to the next operating area is planned	5-30	140 120 176 212 134 525 578	TN TN UP UP UP UP UP	1 2 2 2 3 3 3	6 2 7 7 3 43 55	4.2.4.1 21.19.9 21.15.9 21.17.6 27.4.4 27.31.3 27.36.5	
7.1.1.2 VTUAV search pattern is planned		X					Not in OSD
7.1.1.2.1 selection of an appropriate search pattern	7-15	382 482	UP UP	1 2	27 23	4.2.15.5 21.26.4	
7.1.1.2.7 location of contact symbol is determined on tacplot	8	475	UP	2	19	21.26.1	
7.1.1.2.8 direction of movement of contact symbol	3	481	x				Not in OSD
7.1.1.3 VTUAV waypoint is inserted	3-15	208 404 194 484 481	TN TN UP UP TN	1 1 2 2 3	6 30 7 23 38	4.2.4.2 4.2.26.25 21.17.2 21.26.6 27.28.17	
7.1.1.6 VTUAV time on task is calculated		X					Not in OSD
7.1.1.6.1 location of potential VTUAV refuelling platforms	20	247	UP	1	7	4.1.21.6	

Goal ID and Goal Descriptor	Completion Time (sec)	OSD ID	OSD Operator	CMC Scenario Segment	OSD Page Number	CMC IPME Model Task ID	Notes
7.1.1.6.2 estimated CPF location at time off task	8	254	UP	1	11	4.1.21.9	
7.1.1.6.3 VTUAV fuel on board and average fuel flow	5	256	UP	1	7	4.1.21.7	
7.1.1.6.4 rough VTUAV time on task is calculated	4	246	UP	1	7	4.1.21.2	
7.1.1.6.5 precise VTUAV time on task is calculated	10-20	258 486	UP UP	1 1	11 35	4.1.21.14 4.2.29.8	
7.1.1.6.6 any problems associated with refuelling	10	488	UP	1	35	4.2.29.7	
7.1.1.8 VTUAV activities are planned	10	210 221	TN UO	1 1	10 10	4.2.4.3 4.2.4.37	
7.1.1.9 VTUAV planning activities are monitored	10	223	UP	1	11	4.2.4.35	
7.1.1.10 VTUAV route is plotted	12	214 483	UP UP	2 2	7 23	21.17.7 21.26.5	
7.1.1.11 handover of VTUAV has been prepared	7	590	TN	3	54	27.36.11	

List of symbols/abbreviations/acronyms/initialisms

AF	Air Force
ASO	Acoustic Sensor Operator
CAMA	CF AF MOSID Application
CF	Canadian Forces
CFEC	Canadian Forces Experimentation Centre
CPF	Canadian Patrol Frigate
CHOGM	Commonwealth Heads of Government Meeting
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
HR	Human Resources
HR(mil)	Human Resources – Military
HSI	Human Systems Integration
IPME	Integrated Performance Modelling Environment
ISAR	Inverse Synthetic Aperture Radar
ISMAT	Integrated Simulation Manpower Analysis Tool
JATO	Jet Assist Take-Off
JSI	Job Similarity Index
LCol	Lieutenant Colonel
MALE	Medium Altitude Long Endurance
MOC	Military Occupational Code
MANPRINT	MANpower and PeRsonnel INTegration
MOS	Military Occupational Structure
MOSART	Military Occupational Structure Analysis, Redesign, and Tailoring
MOSID	Military Occupational Structure Identification
NASO	Non-Accoustic Sensor Operator
OSD	Operational Sequence Diagram
PSF	Performance Shaping Function

R&D	Research & Development
ROC	Regional Operations Centre
SA	Scientific Authority
SME	Subject Matter Expert
TACNAV	Tacital Navigator
TK	Task and Knowledge statement
TSK	Task, Skill, and Knowledge statement
UAV	Uninhabited Air Vehicle
US	United States

DOCUMENT CONTROL DATA
(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.) Publishing: DRDC Toronto 1133 Sheppard Ave. W., Toronto, ON, M3M 3B9 Performing: Contractor Alion Science and Technology, 4949 Pearl east circle, Boulder, CO, USA Monitoring: Contracting: DRDC Toronto 1133 Sheppard Ave. W., Toronto, ON, M3M 3B9	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Integrating occupational characteristics into human performance models: IPME versus ISMAT approach (U)
(U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Christy Lorenzen

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
August 2009	102	9

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Contract Report

8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development − include address.)

Sponsoring: DRDC Corporate
Tasking: DRDC Corporate

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
13pv	W7711−057948

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document)	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.)
DRDC Toronto 2009−059	

11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.)

Unlimited distribution

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11), However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited announcement

DOCUMENT CONTROL DATA

(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

(U) This project studied the incorporation of military occupational data into a generic human performance modelling software, the Integrated Performance Modelling Environment (IPME). It has explored the use of modelling and simulation (M&S) for addressing the CF personnel and manpower issues. Particularly, a set of Canadian Air Force occupational specification data were integrated into IPME. This reported study documents our effort to validate this new modelling capability. The Unmanned Aerial Vehicle (UAV) mission modeled in IPME was based on Kobierski (2004). The crew from the model consists of operators defined by the job−related task, skill and knowledge statements from the occupational data. Based on the task data incorporated in the model, we used a Job Similarity Index (Farrell et al., 2006) as an indicator for predicting operator performance. To confirm the validity of this approach, we originally planned to replicate the same UAV model in US Army's IMPRINT and compare the performance predictions made by these two different modelling toolkits. However, due to the lack of access to IMPRINT, the Integrated Simulation Manpower Analysis Tool (ISMAT) was used. As a personnel modelling tool, ISMAT was developed primarily for targeting naval applications. As a result, this study focused on comparing the different personnel modelling approaches between IPME and ISMAT. Their differences are documented in this report, with a highlight on future IPME research and development directions.

(U) L'objet du projet était d'étudier l'intégration de données sur les groupes professionnels militaires dans un logiciel de modélisation générique de la performance humaine appelé Integrated Performance Modelling Environment (IPME). Ce projet a permis d'explorer l'utilisation de la modélisation et de la simulation (M&S) pour tenter de résoudre les problèmes de personnel et de main−d'œuvre au sein des FC. Plus particulièrement, un ensemble de données sur la structure des groupes professionnels militaires de l'Aviation canadienne a été intégré dans IPME. L'étude menée documente les efforts déployés pour valider ce nouveau logiciel de modélisation. La mission des engins télépilotés (UAV) modélisée dans IPME reposait sur les travaux de Kobierski (2004). L'équipage du modèle consiste en opérateurs définis par les énoncés de tâches, d'habiletés et de connaissances reliées au travail, établis à partir des données sur les groupes professionnels. Nous avons utilisé un index de similitude des emplois (Farrell et al., 2006), basé sur les données sur les tâches intégrées dans le modèle, comme indicateur pour prédire la performance des opérateurs. Pour confirmer la validité de cette approche, nous avions initialement prévu de reproduire le même modèle d'engin piloté (UAV) dans l'outil IMPRINT (Improved Performance Research Integration Tool) de l'Armée américaine et de comparer ensuite les prévisions en matière de performance produites par ces deux boîtes à outils de modélisation. Cependant, comme IMPRINT n'était pas accessible, c'est l'outil ISMAT (Integrated Simulation Manpower Analysis Tool) qui a été utilisé à la place. En tant qu'outil de modélisation du personnel, ISMAT a été développé essentiellement pour cibler les applications navales. Par conséquent, cette étude a surtout consisté à comparer les approches de modélisation du personnel différentes que sont IPME et ISMAT. Les différences entre les deux sont documentées dans ce rapport, l'accent étant mis sur les orientations futures de la recherche et du développement portant sur IPME.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Human performance models; IPME; ISMAT; MOSID; Occupational characteristics

UNCLASSIFIED